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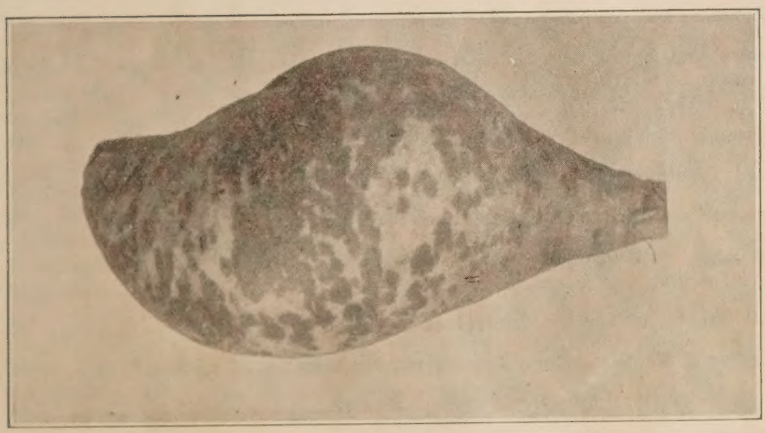
A Chemical Control of Sweet Potato Scurf



SCURFED SWEET POTATO

THE AGRICULTURAL EXPERIMENT STATION
OF THE
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A CHEMICAL CONTROL OF SWEET POTATO SCURF

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Plant Pathologist

INTRODUCTION

In 1890 Halsted (3) described the scurf disease of sweet potatoes and named the causal fungus *Monilochaetes infuscans*. In 1916, twenty-six years later, Harter (5) and Taubenhaus (18) conducted independent studies on the morphology and physiology of the causal organism, adding to our knowledge certain facts on these subjects that were not brought out in Halsted's studies. In 1915, Taubenhaus (17) obtained a control of scurf by treating the diseased sweet potato for ten minutes with a 1 to 1000 mercuric chloride solution. More recently (9), (13), (6), very irregular and unsatisfactory results of scurf control were obtained with the same seed treatment and with others sometimes recommended indicating a need for further research on this subject. In the meantime (9), (10), (11), (12), (13), (1), it was shown that an application of 300 pounds of sulfur per acre on the infected soil previous to planting greatly reduced infection. This treatment left the soil more acid than was desirable for other crops used in rotation with sweet potatoes and was not generally applicable for scurf control (11). The disease has increased in importance as a result of market discrimination. The elimination of the disease from good market grades has further increased its importance because it is so widely distributed, and is prevalent in all areas where the crop is grown. Observations and experiences with methods of control recommended up to this time showed that generally they were not satisfactory and sometimes of no value. The selection of disease-free seed stock was the only practical control method available and it had some limitations. As a result of investigations conducted during the past four years further information was secured on the control value of seed potato treatments and the morphology and physiology of the causal fungus. During these studies another practical method of securing disease-free plants was determined. For the first time a plant treatment was found that is effective, simple, economical, and practical for the control of this disease.

ECONOMIC IMPORTANCE AND LOSSES

The scurf disease (fig. 1) is prevalent in all states and in many areas where the sweet potato crop is grown (7). In 1890 Halsted (3) reported that the disease was so prevalent that, "on some soils nearly every potato will be wholly or in part covered with scurf." In a wet year in New Jersey (11) infection is reported as occurring in 70 percent of the

fields and on 30 percent of the plants. In Arkansas (7) the disease is reported as occurring in all plantings and as the most prevalent disease. In Delaware (18) it is said to be prevalent on practically all sweet potato land. In South Carolina, A. E. Schilletter, of the Horticultural Department, states that the disease is of much economic importance throughout the state. The disease is found throughout North Carolina. It is most severe in the loamy soils of the Piedmont area, and all areas west of the coastal plain. It is much more prominent on such soils as the Cecil and Granville sandy loam types than on the Norfolk and other light sands. The reports show that the disease is well established in all commercial sweet potato areas. A broad survey throughout the country may show a much greater distribution and prevalence than is now given for many areas. Wet seasons, along with soils treated with lime, manure, and legume hay are especially conducive to greater severeness of scurf.

Fig. 1—Plant on left with badly scurfed potatoes not treated. Plant on right with healthy potatoes dusted with sulfur.

The scurf disease is condemned because: (1) It produces a dark brown discoloration of the periderm tissue, making necessary an elimination or only a trace tolerance in good market grades. (2) It reduces the weight, sometimes below any market value, as a result of shrinkage (fig. 2 and 17). Losses are reported as varying from a trace to 3 percent (7). These losses probably refer to shrinkage and market value. If so they are indeed very low, because the loss in market value alone

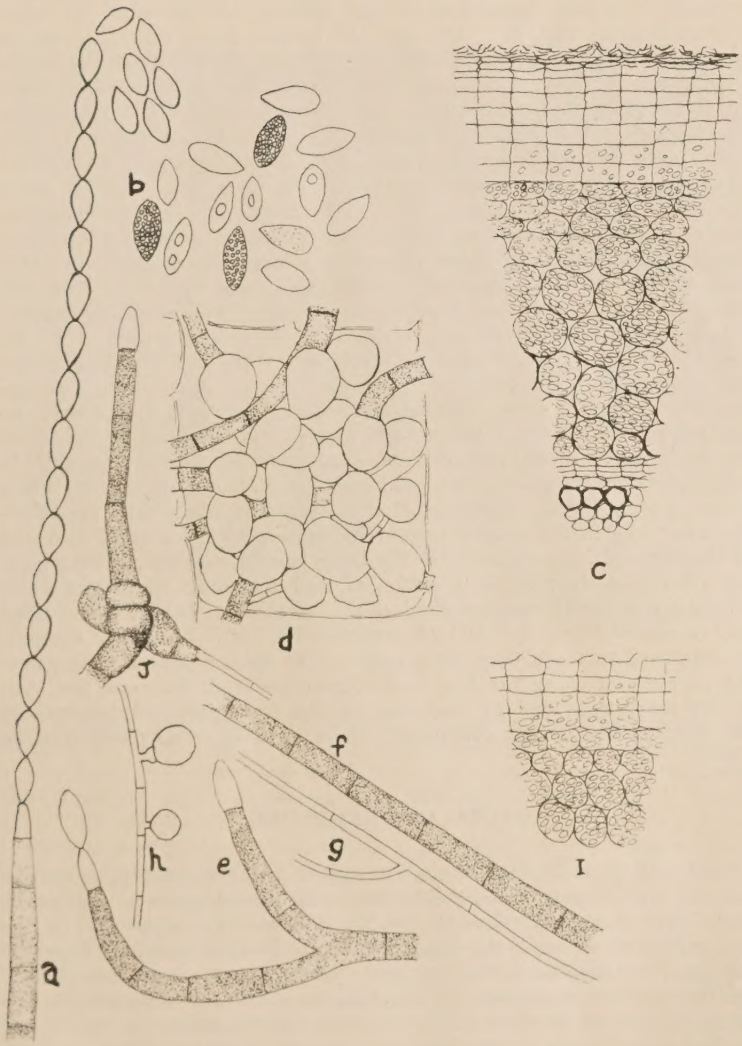

Plate 1—*Monilochaetes infuscans* (a) Chain of spores, (b) Spores in different stages of development, (c) Section through periderm, cortex, and cambium of old stem, (d) Intracellular sclerotial formation of fungus in periderm, (e) Short hyphae, (f) Large brown mycelium, (g) Small hyaline mycelium, (h) Haustoria like development, (i) Young root showing periderm and part of corky tissue, (j) Sporophore with enlarged base cells.

would easily be greater than these estimates, and besides, loss by shrinkage which is always prominent among scurfed potatoes must be taken into consideration (fig. 3). Although the fungus does girdle the smaller potatoes (fig. 4), it is questionable, in view of results obtained during the past six years, whether any loss in yield can be claimed. Plants with severely infected roots and stems transplanted in July always give reduced yields, but the losses under such conditions may easily be contributed to a number of causes other than diseases, such as is reported by Stuckey (16) who found that: "For late planting, pieces of vines gave heavier yields than plants." Losses indirectly due to scurf are caused by such organisms, as *Trichoderma köningi, Penicillium lutenum, Fusarium oxysporium, Rhizopus nigricans,* and others, since these fungi invade the diseased potatoes more readily than potatoes not scurfed, and cause a variety of soft and dry rots in storage. Shrinkage of scurfed potatoes ranges from 10 to 35 percent (9). It is suppressed at 50 degrees Fahrenheit but increases in severeness with aeration and higher temperature. It is obvious that irregularities in maintaining storage temperatures, partly due to very diverse storage systems throughout the sweet potato areas, are favorable to a very great difference in the losses from shrinkage. Selecting for good grades during periods of sale in which favorable conditions are produced for *Rhizopus nigricans* which destroys a very large percentage of the scurfed potatoes that are eliminated from the better grades results in another indirect scurf loss unless another and immediate outlet for their sale is obtained. Putting all these effects together as indirect losses and including the losses from shrinkage and lower market grades, the total loss due to scurf may easily be placed between 7 and 15 percent with individual losses amounting sometimes to more than 35 percent. The actual total loss is somewhat reduced by using for hog feed scurfed potatoes that are not suitable for marketing, and by disposing of the sound scurfed potatoes in small city markets, where fortunately there is little or no discrimination as yet.

CAUSE AND SYMPTOMS

Scurf, soil stain, mottle or rust is caused by *Monilochaetes infuscans* E. & H. The fungus attacks only the underground parts of the sweet potato. The periderm tissue is readily invaded, probably due to the outer and in some cases the inner cell walls being broken, as they become dry, hard and bark like. A dark brown circular spot, conspicuous from the pigment maintained in the fungous parts and diffused into the tissues, is observed in from six to ten days when potatoes are inoculated and maintained moist. The fungus spreads in all directions. Spots coalesce after extensive fungous growth occurs and the entire potato may become brown, dark brown, and finally black when the sporophores and hyphae, the darkest parts of the fungus, become very numerous. The periderm is composed of a layer of 6 to 20 cells devoid of or with only traces of starch. The older stems (plate 1c) and roots possess a periderm of greater depth than developing or rapidly growing roots (plate 1i). The fungus advances with the periderm as it, with the infected

tissue, would be sloughed off into the soil if it did not keep pace with the developing periderm.

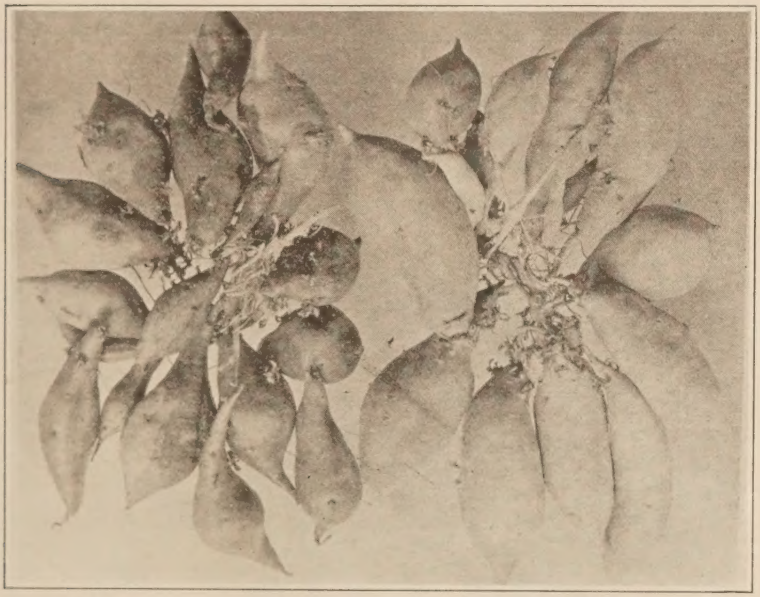

Fig. 2—Same as figure 1 after 60 days' storage, showing shrinkage of scurfed potatoes.

Sometimes the infected periderm peels in large sheets soon after potatoes are stored (fig. 5). The colorless mycelium invades the periderm to a greater depth than the more coarse strands. The periderm formation (plate 1c, fig. 8b) was partly explained by Artschwager (2) who said, "The peripheral cells are covered by a root epidermis which soon becomes torn and is later replaced by a periderm. 'A superficial periderm replaces in protective function the root epidermis.' 'The thin-walled cells composing it form parallelopipeds with the shortest diameter in the radial axis of the organ.' 'The outer periderm cells become partly lignified and are progressively sloughed off.' 'The periderm increases in thickness by a phellogen which remains active throughout the season, forming new cells to replace those which are sloughed off as the surface of the fleshy root expands'." This phenomena is not only confined to the fleshy root but it is equally as prominent on the enlarging stem.

The sloughing off of the periderm is best demonstrated when a badly scurfed stem is treated with control chemicals and planted since during the growing season the entire discolored and infected tissue becomes sloughed off as the stem enlarges. By harvest the stem is free from infection and the brown discoloration (fig. 1). Whether or not the disease increases the thickness of the periderm was not determined, but the

great desication of scurfed potatoes as compared with healthy potatoes indicates that the periderm tissue is made more porous after the mycelium enters it. Scurf does not produce any symptoms on the parts above the ground and there seems to be no means of determining whether or not the roots and potatoes are scurfed by examining leaves and vines.

MORPHOLOGY AND PHYSIOLOGY

The germination of spores, and growth of the mycelium are readily obtained in a large number of both solid (fig. 6) and liquid (fig. 7) media prepared synthetically or from plant products. Growth was good

Fig. 3—Shrinkage of badly scurfed potatoes showing that the quality is destroyed.

at 25° C. on media prepared with sweet potato, Irish potato, rice, corn meal, soil, hay, and manure. All parts of the fungus were well-developed and spores were produced in both liquid and agar preparations. In liquid media growth is much faster, but sporulation slower than on solid media. In the former media, the mycelium had extended 10 times further from the germinating center than it had on the solid media five days after inoculation. The formation of hyphae, sporophores, and the multiple branching of the extremely small hyaline mycelium produces a stroma-like growth in both types of media (figs. 6 and 7). After seven days' growth the colonies rarely exceed 2 mm. in diameter on different media to which agar is added. The colonies are hyaline at first, but darken as the large mycelium and sporophores develop. The upper surface becomes ashen in color (fig. 6) when the spores are developed in abundance.

The submerged mycelium is probably as thin as any produced by fungi (plate 1g), (fig. 8c). It is .2 to 1 μ in diameter, and being small

and hyaline makes it difficult to trace in the periderm. It is septate, branches extensively and becomes so dense in solid culture media that a large amount of media is removed with the mycelium during the removal of a colony. What may be called a dark brown mycelium (plate 1f) is produced on the surface and in the first cells. It varies from 3 μ to 6 μ in diameter, is septate and thick-walled. In the upper cells of the periderm, a club-like fungous growth is produced somewhat similar in appearance to the cells seen when a young sclerotium of the *Corticium vagum* fungus is crushed. These cells are crowded together in such a way as to suggest a definite intracellular sclerotial formation (plate 1d). The naturally broken cell walls make it impossible to determine whether or not haustoria are produced. However, either haustorai or fungous parts like haustoria are developed (plate 1).

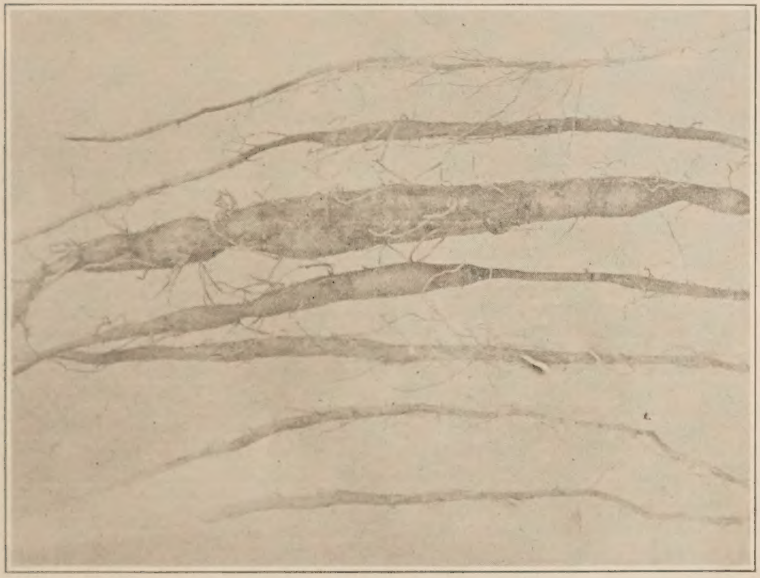

Fig. 4—Small potatoes girdled by the scurf disease.

When a thin longitudinal section of infected tissue is treated with ammonia water until most of the brown pigment is removed, and then stained very lightly with eosin, the sclerotial formation is clearly seen (fig. 8a and plate 1d). These cells are somewhat similar in size and appearance to the first cell of the sporophore, which is large and thick-walled. The sporophore is septate with a ball-like cell at the base, and a hyaline spear-like apex (fig. 8e and 1j). It arises from the mycelium in the first cells of the periderm and extends perpendicularly to the surface. It varies from 3 μ to 7 μ in diameter and from 100 μ to 300 μ in length. Spores are borne in chains of 15 to 30 at the apex of the sporophore (plate 1a). They are produced in great numbers in the soil

and in pure culture. The spore chains are rarely seen on sporophores on the plant parts because soil conditions cause them to separate from the sporophore. They are readily seen in pure culture and are easily broken up when tapped lightly with a needle or when placed in any solution.

An examination of scraped periderm tissue shows the spores in great abundance indicating how abundantly they are produced and discharged into the soil. The abundance of spots, such as are shown on the cover photograph, brought about by spore inoculation only, is further proof that the spore production is very great in the soil. The fungus produces mycelium, sporophores, and spores at any depth to which the potato extends in the soil, even to ten inches. The spores are ovate, hyaline and guttulate. Germination takes place readily in many nutrient media and the mycelium becomes extensively branched.

Fig. 5—Natural peeling of diseased periderm tissue on badly scurfed potatoes.

These studies further show that the mycelium is well-developed in the tissues (fig. 8d, plate 1d). Halsted (3), and later Taubenhaus (18), found that the spores are borne in chains, but Harter (5) reported them solitary and continuous, and concerning the fungus stated that, "It was found that the organism on the host consisted merely of sporophores and conidia." None of these authors refer to the periderm infection, but Taubenhaus (18) probably had this tissue in mind when he stated that, "Soil stain, or scurf is a disease of the epidermis," but shows quite clearly a drawing of the periderm with mycelium imbedded in the tissues. Neither investigator indicated the presence of the club-like cells and

sclerotial formation in the upper cells of the periderm. It is obvious that spore, sporophore and mycelium measurements would vary slightly for any description, but only slight differences occur in descriptions of these parts.

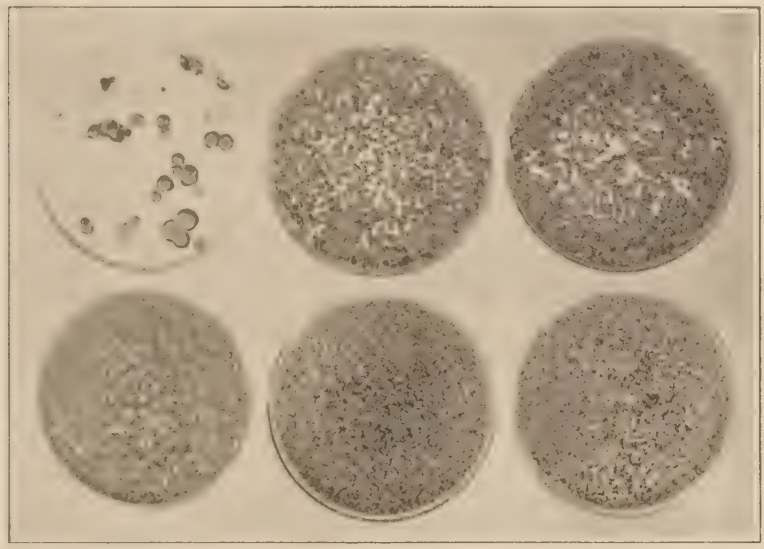

Fig. 6--*Monilochaetes infuscans* in plate culture.

The line of demarcation between periderm and cortex is not always pronounced, but cells of the latter are more or less round and contain much starch (plate 1c). The mycelium is confined to the periderm proper. The ready entrance to this tissue is facilitated by broken walls. The fact that there is no epidermis but a periderm of lignified cells with broken walls may account for the fungus occurring in the periderm and not in the cortex. Freshly sliced potatoes inoculated with the causal fungus become infected as readily as potatoes with a naturally formed periderm. However, the sliced potato immediately develops a periderm, corresponding somewhat in character to the natural periderm (fig. 9).

DISSEMINATION AND SPREADING ACTIVITIES

Absolute proof of how *Monilochaetes infuscans* became so widely distributed in the sweet potato areas can never be obtained. During the course of these studies some information was obtained that suggests that the organism is one of the common soil microörganisms. The fact that the fungus is annually carried on diseased plants and potatoes from one area to another would seem to indicate that the present wide distribution came about through the distribution of diseased potatoes and plants. The disease is so prevalent on both plant (fig. 10) and potato seed stock that it could be spread throughout the sweet potato area in

the course of 35 years. Certification rules, in which there is a trace tolerance, are of no value in preventing dissemination and besides thousands of potatoes and plants not certified are used annually throughout the sweet potato areas. Complete elimination from the seed and plant stock is not recognized everywhere as being necessary as a practical precaution against the disease. Furthermore, heavy infection may often occur on plantings made from apparently healthy potatoes selected from individual hills and bins. Spore contamination has made such selections very uncertain, and even a trace of plant infection may result in total plant infection when efforts are made to revive wilted plants by dipping together bunches of plants in the same pail of water immediately before transplanting. In many instances the dissemination was not intended but due to too much confidence placed in seed treatments.

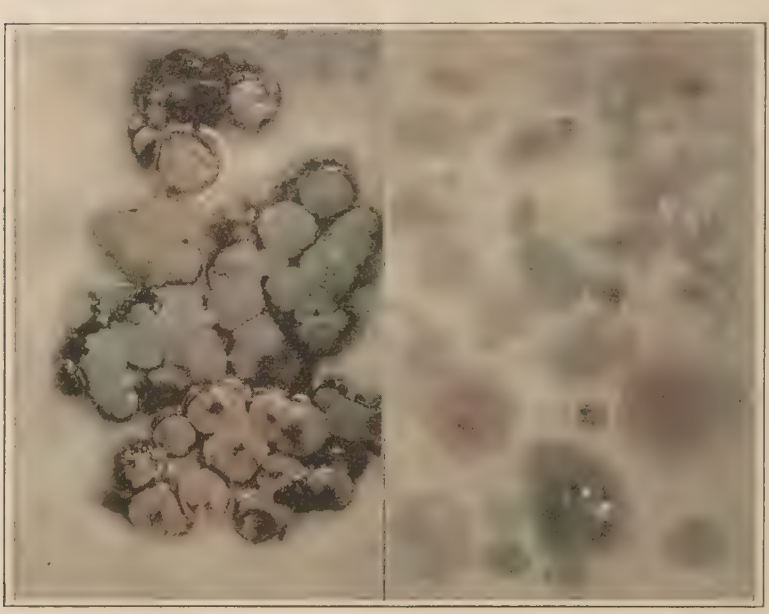

Fig. 7—*Monilochaetes infuscans* in liquid media with sulfur in medium shown on the right.

The mycelium grows in all directions on the roots and stem from infected centers. In soils of neutral reactions and in soils containing such organic media as barnyard manure, and peavine hay the organism advances to all parts much more rapidly than when the soil is deplete in organic matter and of a high acid condition. In loamy soils the roots are sometimes badly scurfed before plants are removed from the plant bed. Heavy infection at the time of transplanting is favorable for heavy infection of potatoes, since a large amount of inoculum is supplied at the very beginning of the growing season. The spreading of the mycelium is sometimes confined to the stem and roots nearest to the stem even after four and five months' growth. Many plants were examined in

which infection was confined to potatoes just beneath the stem while those on the same plant borne above the infected parts and some distance away remained free (fig. 11). This condition is mostly found on light sandy soils, because on loamy soils the mycelium spreads much more extensively, resulting in heavy infection (fig. 1).

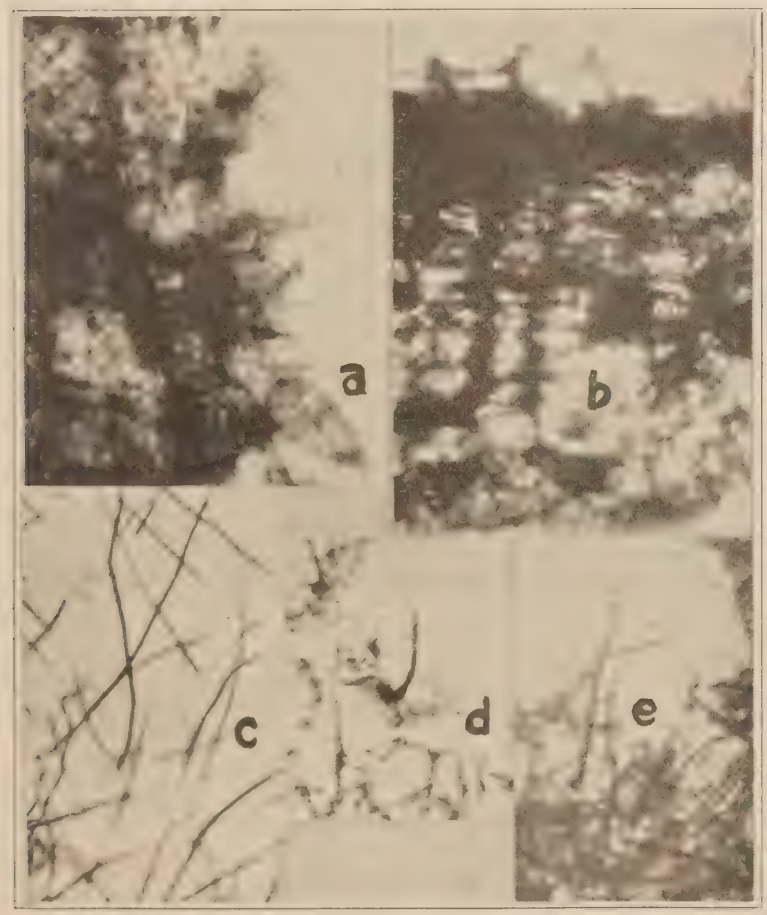

Fig. 8.—Photomicrographs of (a) Intracellular sclerotial formation of *Monilochaetes infuscans*. (b) Periderm tissue and broken walls of upper cells. (c) Large and small mycelium. (d) Sporophore developing from mycelium in the tissues. (e) Sporophores numerous on surface of diseased potato.

The discharged spores are responsible for the greatest amount of potato infection. They are discharged into the soil throughout the growing season, and reach the potato through crevices in the soil produced by the enlarging potato and in water moving downward. The greatest

and first infection takes place near the stem and also becomes most severe along the sides where spores are spread (fig. 12). Potatoes inoculated at bedding time showed heavy infection 20 days later along the smeared surface and the fungus continued to spread rapidly on the margins (fig. 13). This spread was sufficient to give a very high percentage of diseased plants. The fact that the disease is less severe on such varieties as the Porto Rico, which develops the potatoes further away from the stem than the Jersey and Nancy Hall varieties, is further proof of the importance of relations of the spreading activities of the mycelium and spores to the severeness of the disease.

Fig. 9—*Monilochaetes infuscans* developing on calloused tissue of cut surfaces.

There is no definite or rapid spread of the fungus through the soil substrata. Tests conducted with distance plantings showed that plants became diseased in contact with diseased plants and potatoes, but healthy plants set as close as six inches apart from diseased plants did not become diseased by harvest. Therefore the common practice of transplanting from twelve to twenty inches apart in the row is a spacing that does not permit infection of one plant from another. The studies on the spreading habits of the fungus, show definitely that potato infection is more severe when diseased plants are used, than when healthy plants are transplanted in infected soils. The life cycle in which the organism lives on the potato, is spread to the plant in the plant bed, and to the potato in the field is an aggressive one.

In this state the diseased potato and plant are the primary sources of infection, since vine cuttings transplanted on eight farms showed no evidence of infection on seven farms. Other observations where vine cuttings were transplanted verified these findings. The organism does live over in the soil in many fields, but there seems to be no evidence of how long or under what conditions.

SEED TREATMENT INVESTIGATIONS

Investigations of seed treatments for the control of scurf were first conducted by Taubenhaus and Manns (17) who reported control to be positive with mercuric chloride, and negative with formaldehyde. The same mercuric chloride treatment of 10 minutes at a strength of 1 to 1000 was reported by other investigators (13), (9), (6) to be uncertain and to give only partial control, when complete control is both important and desirable. The mercury compounds, however, offer the most promising results. Excellent control was obtained with 35 percent hydroxymercurichlorophenol when used as a dust at the rate of 2 ounces per bushel (13) but retardation of germination was so great as to discourage the use of this material for practical applications. Observations on practical seed treatment showed both positive and negative results and that the badly scurfed potatoes were more resistant to the chemical treatments than those that were slightly scurfed. The fact that mercuric chloride and hydroxymercurichlorophenol treatments were partly effective in controlling the fungus, although both caused retardation in germination, suggested that a practical seed treatment control was possible. Further investigations conducted with many compounds used at various strengths and for different lengths of treatment gave more information on this subject.

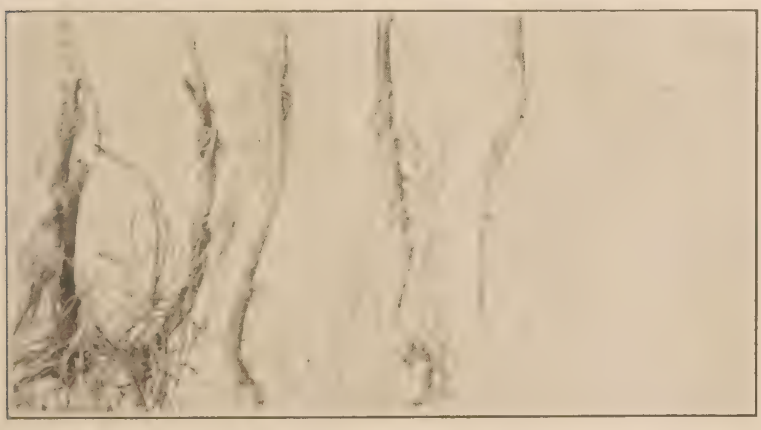

Fig. 10.—Scurfed roots and stems on left, healthy roots and stems on right.

Pure culture studies with *Monilochaetes infuscans* were conducted as a means of determining a relative toxicity of chemicals to the fungus. A sweet potato medium prepared by cooking 300 grams of cured Yellow Jersey sweet potato until easily macerated and strained to make 1000 cc. was used in amounts of 25 cc. in 100 cc. Ehrlenmeyer flasks. The chemicals were added to make different strengths, the medium steamed, and then inoculated with spores of *Monilochaetes infuscans*. The chemicals used are given in table 1, and consist of organic and inorganic mercury compounds, sulfur, calcium oxide, magnesium oxide, Bordeaux mixture,

formaldehyde, copper carbonate, emulsified phenol, and cresol compounds. The results showed that all chemicals used were toxic to the fungus, and the majority in dilutions much weaker than the potato would tolerate. Even compounds such as formaldehyde inhibited fungous growth at 1 to 1,000 with mercuric chloride 1 to 10,000. It is obvious from these results that the problem is not to find a chemical that is toxic to the scurf organism necessarily, but to find one that will perform in one of two ways or both; namely, penetrate the periderm and kill the fungus as it exists in the tissues or stop the development of the mycelium on the surface as a means of preventing plant infection. The causal fungus is not readily isolated, and cultural studies or attempts to isolate the fungus from diseased potatoes after treatment was abandoned as not satisfactory. The method of treating the diseased potatoes and measuring the infection by examining the plants was followed, since results could be obtained when the plants were removed from the potato, and at the end of the growing season after transplanting them in the field or making mass plantings in pots.

Treatments of badly scurfed potatoes were given with chemicals found to be toxic to the fungus in pure culture studies. All substances were used at strengths much greater than had inhibited fungous growth in pure culture but in the range of potato germination tolerance as was determined in preliminary studies. The Yellow Jersey and Nancy Hall varieties were used for these tests, because potatoes of these varieties are more uniformly infected and a larger number of potatoes of equal sizes could be selected. Four quart measures of potatoes of relatively uniform sizes and numbers were used. Small potatoes, commonly classed as culls, were used because greater uniformity was possible than could be obtained with larger potatoes. The potatoes were also scurfed over the entire surface and were sound or as nearly free from shrinkage as can be obtained with scurfed potatoes. It was necessary to use sound potatoes because those showing much shrinkage decayed badly in the plant bed and germinated poorly, making it impossible to determine accurately results on germination. Treatments were repeated from three to five times and were applied immediately before bedding. Dust treatments were made by placing the potatoes in a large paper bag, adding the dust and tilting until potatoes were well coated. This was not a difficult operation, because the dusts adhered to the surface in large amounts, and gave both uniform and heavy coatings. The potatoes were bedded in sand, sawdust, and coal ashes in wooden tubs and earthern pots. The ashes proved most satisfactory, since greater uniformity in germination was obtained. Mass planting in pots and transplanting in the field gave a more accurate determination of the control value, since infected periderm tissue sometimes remained on the sprout when removed from the diseased potato. The presence of mycelium and spores on the plant could not be determined accurately even with a microscope except when well advanced. The general procedures of all tests were the same unless otherwise stated.

TABLE 1

The Effect of a Large Number of Chemicals on the Control of the Causal Fungus of the Scurf Disease When Diseased Seed Potatoes Are Treated

Chemical	Strength and Treatment	Plants Number	Plants Scurfed Percent. June 1
Check (not diseased)		260	0.0
Check (diseased)		285	100.0
Hydroxymercurichlorophenol (a)	1 to 20 for 10 minutes	264	54.0
Hydroxymercurichlorophenol	1 to 100 for 10 minutes	180	22.0
Hydroxymercurichlorophenol	4 oz. to bushel	390	40.0
Mercuric Chloride	1 to 1000 for 10 minutes	250	46.0
Sulfur	4 oz. to bushel	265	60.0
Sulfur (Colloidal) (d)	4 oz. to bushel	250	62.0
Potassium Permanganate	1 to 100 for 10 minutes	285	100.0
Calcium Oxide	1 to 10 for 10 minutes	130	100 0
Magnesium Oxide	1 to 10 for 10 minutes	215	100.0
Lime Sulfur	1 to 10 for 10 minutes	115	100 0
Bordeaux Mixture	20–20–50 dip	260	100.0
Formaldehyde	1 to 100 for 10 minutes	228	100.0
Calcium Hydrated	4 oz. to one bushel	85	100 0
Calphene	4 oz. to one bushel	285	100.0
Copper Caronate 50%	4 oz. to one bushel	195	100.0
Monohydrated Copper Sulfate and lime Dust 25%	4 oz. to one bushel	280	100 0
[illegible]	1 to 100 for 10 minutes	340	100 0
Emulsified Phenol (c)	1 to 100 for 10 minutes	349	100 0

(a)—Trade name of Compound used is "Semesan" and "Semesan Bel".
(b)—Trade name "Lysol"
(c)—Trade name "Phenoco."
(d)—Trade name "Kolodust."

The results given in table 1 show that potassium permanganate, calcium oxide, calcium hydroxide, magnesium oxide, lime sulfur, Bordeaux mixture, formaldehyde, calphene, copper carbonate, 25 percent monohydrated copper sulfate plus 75 percent hydrated lime, and emulsified phenols and cresols did not control the organism, since plant infection of treated potatoes was 100 percent. Furthermore, calcium

hydroxide, magnesium oxide, and lime sulfur retarded germination. Further trials indicated that the lime compounds may seriously retard germination. Potassium permanganate and emulsified phenols and cresols sometimes caused marked stimulation. Treatment for 10 minutes in 10 percent hydroxyn ercurichlorophenol 1 to 20 strength gave 46 percent clean plants in comparison with 60 percent clean plants when used as a dust at the rate of 4 ounces per bushel. Slight stimulation was produced by the liquid treatment, but retardation was frequently severe after

TABLE 2

THE RESULTS OF TREATING SCURFED SWEET POTATOES WITH MERCURIC CHLORIDE IN DIFFERENT STRENGTHS AND FOR DIFFERENT PERIODS OF TIME

Chemical	Strength	Treatment Minutes	Plants Number	Plants Scurfed Percent
Check (not diseased)			460	0.0
Check (diseased)			415	100.0
Mercuric Chloride	1 to 1000	60	140	10.0
Mercuric Chloride	1 to 1000	30	250	19.2
Mercuric Chloride	1 to 1000	20	365	26.0
Mercuric Chloride	1 to 1000	15	362	37.6
Mercuric Chloride	1 to 1000	10	361	47.3
Mercuric Chloride	1 to 500	60	135	8.1
Mercuric Chloride	1 to 500	30	180	10 5
Mercuric Chloride	1 to 500	20	288	13.5
Mercuric Chloride	1 to 500	15	300	26.7
Mercuric Chloride	1 to 500	10	320	44.7
Mercuric Chloride	1 to 200	60	140	5.0
Mercuric Chloride	1 to 200	30	181	11.0
Mercuric Chloride	1 to 200	20	174	14.3
Mercuric Chloride	1 to 200	15	285	20.9
Mercuric Chloride	1 to 200	10	324	24.0

the dust treatment. Treatment with 35 percent hydroxymercurichlorophenol applied at the rate of 1 to 100 for 10 minutes gave 78 percent clean plants, but greatly retarded germination. Mercuric chloride 1 to 1,000 strength used 15 minutes gave 54 percent clean plants. Sulfur gave 38 and 40 percent clean plants. These results show that the mercury and sulfur treatments were not as effective as is desired, but indi-

cate sufficient reduction in the infection to warrant further trials. Although emulsified phenol and cresol compounds and potassium permanganate stimulated germination, they were eliminated from further trials, because satisfactory germination is obtained in practice without the use of any treatment.

The results of treating scurfed potatoes with mercuric chloride in strengths of 1 to 200, 1 to 500, and 1 to 1,000 for 10, 15, 20, 30, and 60 minutes are given in table 2. All strengths of this chemical show a large reduction in the percentage of infection but none of the treatments gave complete control. All retarded sprouting, some severely. The number of sprouts reduced was 54 when 1 to 1,000 was used for 10 minutes. Retardation amounted to 165 plants after treating 30 minutes and to 275 plants after 60 minutes. The infection was also reduced 52.7, 62.4, 74.0, 80.8, and 90 percent respectively, for the 10-, 15-, 20-, 30-, and 60-minute treatments. These results indicate that the disease would be reduced

TABLE 3

The Effect of Hot Solutions (50° C.) of Mercuric Chloride and Formaldehyde on the Control of the Causal Fungus of the Scurf Disease When Diseased Potatoes Are Treated

Chemical	Strength	Length of Treatment Minutes	Plants Scurfed June 1 Percent	Plants Scurfed Aug. 1 Percent
Check (not diseased)		3	0	0
Check (not diseased)		5	0	0
Check (not diseased)		7	0	0
Check (diseased)		3	100.0	100.0
Check (diseased)		5	100.0	100.0
Check (diseased)		7	100.0	100.0
Mercuric Chloride	1 to 1000	3	47.1	100 0
Mercuric Chloride	1 to 1000	5	44.9	100.0
Mercuric Chloride	1 to 1000	7	37.5	100 0
Formaldehyde	1 to 100	3	100.0	100.0
Formaldehyde	1 to 100	5	100.0	100.0
Formaldehyde	1 to 100	7	100.0	100 0

satisfactorily if retardation could be overcome following the longer treatments. The 1 to 200 and 1 to 500 strengths show slightly greater control than was obtained with the 1 to 1,000 strength, but the differences in control are not significant. The treatments with 1 to 500 strength for 10, 15, 20, 30, and 60 minutes gave a reduction of infection over that of

the 1 to 1,000 strength of 2.6, 10.9, 12.5, 8.7, and 1.9 percent respectively. The reduction for 1 to 200 over the 1 to 1,000 was 23.3, 16.7, 11.7, 8.2, and 5.0 percent respectively. However, the retardation of sprouting was much more severe where the stronger treatments were applied.

The results show that mercuric chloride 1 to 200 strength used for 10 minutes may not seriously retard sprouting. It gives a reduction in infection that is comparable with the 1 to 1,000 and 1 to 500 treatments when used for 15 minutes. These results indicate that treatment with mercuric chloride at a strength of 1 to 1,000 for 15 minutes would give the most efficient control with the minimum reduction of germination. The 15-minute treatment is also preferable to the 10-minute treatment, since there was a difference in control of 9.7 percent in favor of the former, with no appreciable difference in germination.

Fig. 11—Plant showing diseased potatoes just beneath the infected stem and healthy potatoes on the upper parts of the stem.

The results of treating scurfed sweet potatoes with mercuric chloride and formaldehyde for 3, 5, and 7 minutes at 50° Centigrade are given in table 3. The hot water alone gave no control. Hot formaldehyde likewise gave no control. Hot mercuric chloride used for 3, 5, and 7 minutes reduced infection to the extent of 52.9, 55.1, and 62.5 percent respectively, which compares favorably with the results given in table 2 for the 10-minute treatment in which the potatoes were treated at 20° C. Plants pulled from the same plots August 1, were infected 100 percent because the fungus had finally spread to all plants. These results indicate that hot chemicals up to the temperature used offers only slight improvement

in the treatment for mercuric chloride. There was retardation in sprouting similar to that pointed out above where these chemical treatments were applied and the potatoes which were not treated decayed badly due to soft rots in the plant bed, even when thoroughly dried before bedding.

Fig. 12.—Potatoes showing spreading activities of the causal fungus from the stem downward to potatoes.

The results of treating scurfed sweet potatoes with hydroxymercurichlorophenol in various strengths and mixed with other compounds are given in table 4. The plants examined June 1, from potatoes treated and bedded April 10, showed that 6 percent hydroxymercurichlorophenol held infection to 15.0 percent. The 35 percent strength completely controlled the disease. The 20 and 10 percent strengths showed 10 and 14.5 percent infection June 1, and 28.9 and 60.9 percent infection August 1. All of these treatments greatly retarded germination. The diseased check consisting of potatoes from the same lot produced an average of 360 plants in comparison with 120, 110, 107, and 10 for the 6, 10, 20, and 35 percent strengths of the chemical. This was a reduction of 66.6, 69.5, 73.1, and 97.3 percent in germination which will prevent the use of this chemical as a dust treatment.

The treatments with 10 percent hydroxymercurichlorophenol mixed with sulfur, with tolomite, and with 25 percent monohydrated copper sulfate and 75 percent hydrated lime in which the latter mixtures made up 90 percent of the dust failed to give satisfactory reduction of the infection. The infection was 36.6, 56.0, and 53.5 percent June 1, in comparison with 100 percent for the check. Retardation of sprouting when mixed with sulfur, copper lime, and tolomite was 66.6, 68.8, and 93.0

TABLE 4

THE RESULTS OF TREATING SCURFED SWEET POTATOES WITH HYDROXYMERCURICHLOROPHENOL IN VARIOUS STRENGTHS AND WHEN MIXED WITH OTHER COMPOUNDS ON THE CONTROL OF THE DISEASE

Chemical	Strength	Plants	Plants Scurfed Percent June 1	Potatoes Diseased Percent Aug. 1
Check (Not Diseased)		380	0	0
Check (Diseased)		360	100.0	100.0
Hydroxymercurichlorophenol 6%a	4 oz. to one bushel	120	15.0	70.8
Hydroxymercurichlorophenol 10%	4 oz. to one bushel	110	14.5	60.9
Hydroxymercurichlorophenol 20%	4 oz. to one bushel	107	10.0	28.9
Hydroxymercurichlorophenol 35%	4 oz. to one bushel	10	0	0
Hydroxymercurichlorophenol 10% Sulfur 90%	4 oz. to one bushel	120	36.6	58.3
Hydroxymercurichlorophenol 10% Tolomite 90%	4 oz. to one bushel	25	56.0	80.0
Hydroxymercurichlorophenol 10% Copper Lime Dust 90% (b)	4 oz. to one bushel	112	53.5	71.4
Hydroxymercurichlorophenol 10%	1 to 5 dip	260	17.3	100.0
Hydroxymercurichlorophenol 10%	1 to 10 dip	390	26.3	100.0
Hydroxymercurichlorophenol 10%	1 to 20 dip	410	36.5	100.0
Hydroxymercurichlorophenol 10%	Paste	155	0.0	0.0
Hydroxymercurichlorophenol 10%	1 to 10 for 10 minutes	375	22.4	81.5

(a)—The hydroxymercurichlorophenol mixtures were prepared and furnished by the E. I. DuPont De Nemours & Company.

(b)—Copper lime dust is composed of 25 percent Monohydrated Copper Sulfate, and was prepared and furhished by the Niagara Sprayer Company.

percent respectively. In the same test, treatments were conducted with hydroxymercurichlorophenol in strengths of 3 and 5 percent mixed with the compounds specified above. These also caused severe retardation of sprouts and at the same time produced no significant control. The 10 percent hydroxymercurichlorophenol used and diluted to 1 to 5, 1 to 10, and 1 to 20 strength gave 82.7, 73.7, and 63.5 percent clean plants June 1, and the 1 to 10 and 1 to 20 strengths actually stimulated germination 30 and 50 plants over the yield of similar potatoes that were not treated. The 1 to 5 strength retarded germination 100 plants, and besides the infection was 100 percent on all plants August 1. The liquid treatment was less effective than the same chemical used as a dust, since the latter treatment had permitted only 60.9 percent infection by August 1. Results

obtained in these studies indicate that the dip method with this chemical at 1 to 10 strength will be equally as satisfactory to use in practice as the 1 to 1,000 mercuric chloride solution.

When 10 percent hydroxymercurichlorophenol was rubbed into the moistened infected tissues 100 percent control was obtained, but germination was retarded 56.9 percent. Using the same percentage of mercury in 1 to 10 strength for 10 minutes' treatments reduced plant infection to 22.4 percent June 1, but it amounted to 81.5 percent on August 1. The dilute strength of this compound stimulated germination, but as already pointed out, this is not always beneficial. In fact, a very great production of sprouts beyond the point where uniformly strong plants are produced is of questionable value, because weak plants which sometimes predominate are less satisfactory for transplanting. The same rule may be applied to slight retardation, because if there is no root injury, potatoes with few plants produce a very large percentage of strong plants. Since strong and weak plants are both susceptible to scurf a full discussion of plant sizes would be out of order. Either slight retardation or slight stimulation of germination are of little concern to the practical grower. The extremes of poor germination and heavy germination are not desirable.

The results of presoaking scurfed sweet potatoes for 6, 12, and 18 hours before treating with disinfectants are given in table 5. Negative control was obtained with formaldehyde. Treating for 15 minutes with mercuric chloride 1 to 1,000 and 10 percent hydroxymercurichlorophenol in 1 to 10 strength gave slightly greater control of scurf on presoaked than on dry potatoes. Scurfed potatoes soaked for 6, 12, and 18 hours and treated with 1 to 1,000 mercuric chloride for 15 minutes and bedded immediately after drying showed an infection of 7.7, 8.2, and 6.9 percent less than was obtained for the same treatments applied to the dry potatoes. The reduction for hydroxymercurichlorophenol was 2.2, 1.1, and .4 percent. The infection after treating dry potatoes was 23.8 percent for mercuric chloride and 22.6 percent for hydroxymercurichlorophenol. The germination of all presoaked potatoes including diseasd potato checks, healthy potato checks, and treated potatoes was greater than for those not presoaked. The increase varied from 1.6 to 22.5 percent. The potatoes free from scurf used for checks showed 8 percent greater sprout production than the diseased potatoes. This condition predominates, and is more often higher, especially if the scurfed potatoes become badly desiccated during storage. The shrinkage alone greatly lowers the germination but more favorable conditions for soft rots, which also develop sometimes even on treated potatoes, may add to the losses.

The results of treating with disinfectants, sweet potatoes free from scurf but inoculated with spores, immediately before bedding are given in table 6. Formaldehyde, which showed no control of the disease when diseased potatoes were treated, reduced spore infection 26 percent August 10. Other chemicals, which did not control the fungus in the infected potato, greatly reduced infection from spores. Infection on mercuric chloride treated potatoes was only 2 percent August 10, 10.5 percent September 5, and 65.5 percent October 10. Total infection would have

occurred at this time if all potatoes had been infected. When the potatoes were harvested and examined October 10, some individual potatoes with plants were not infected. Other potatoes and all plants were severely scurfed. The infection on check inoculated plants was only 70 percent August 10. In this test the expected infection of 100 percent did not occur, due possibly to some of the inoculum being removed in the water blank treatment which was given to conform with the other liquid treatments after inoculation. However, total infection on the check plants occurred by September 3 and October 10.

TABLE 5

THE RESULTS OF PRESOAKING SCURFED SWEET POTATOES FOR 6, 12, AND 18 HOURS AND TREATING WITH DISINFECTANTS FOR THE CONTROL OF THE SCURF DISEASE

Treatment	Strength and Time	Pre soaked Hours	Plants June 1	Plants Scurfed June 1	Plants Scurfed Aug. 1
Check (Not Diseased)		0	80	0.0	0.0
Check (Not Diseased)		6	95	0.0	0.0
Check (Not Diseased)		12	92	0.0	0.0
Check (Not Diseased)		18	98	0.0	0.0
Check (Diseased)		0	65	100.0	100.0
Check (Diseased)		6	72	100.0	100.0
Check (Diseased)		12	73	100.0	100.0
Check (Diseased)		18	70	100.0	100.0
Mercuric Chloride	1 to 1000 for 15 minutes	0	63	23.8	100.0
Mercuric Chloride	1 to 1000 for 15 minutes	6	68	16.1	100 0
Mercuric Chloride	1 to 1000 for 15 minutes	12	64	15.6	100 00
Mercuric Chloride	1 to 1000 for 15 minutes	18	65	16.9	100.0
Hydroxymercurichlorophenol 10%	1 to 10 for 15 minutes	0	75	22.6	100.0
Hydroxymercurichlorophenol 10%	1 to 10 for 15 minutes	6	83	20.4	100.0
Hydroxymercurichlorophenol 10%	1 to 10 for 15 minutes	12	88	21.5	100.0
Hydroxymercurichlorophenol 10%	1 to 10 for 15 minutes	18	81	22.2	100.0
Formaldehyde	1 to 100 for 15 minutes	0	79	100.0	100.0
Formaldehyde	1 to 100 for 15 minutes	6	88	100.0	100.0
Formaldehyde	1 to 100 for 15 minutes	12	90	100.0	100.0
Formaldehyde	1 to 100 for 15 minutes	18	89	100.0	100.0

TABLE 6

The Results of Treating With Disinfectants Sweet Potatoes Free From Scurf but Inoculated With Spores Immediately Before Bedding

Chemical Treatments	Strengths and Amounts Used	Plants Scurfed June 10 Percent	Plants Scurfed Aug. 10 Percent	Plants Scurfed Sept. 3 Percent	Plants Scurfed Oct. 10 Percent
Check (Not Inoculated)		0	0	0	0
Check (Inoculated)		65.3	70.0	100.0	100.0
Mercuric Chloride	1 to 1000 for 15 minutes	1.2	2.0	10.5	65.8
Formaldehyde	1 to 100 for 15 minutes	40.1	44.0	100.0	100.0
Hydroxymercurichlorophenol	35% dust	0	0	0	0
Hydroxymercurichlorophenol	10% dust	10.8	12.8	22.3	41.8
Hydroxymercurichlorophenol	6% dust	8.1	10.5	20 5	42.3
Hydroxymercurichlorophenol 10%	1 to 10 dip	32.5	40.6	51.8	92.5
Sulfur	Dust	23.1	24.5	33.7	35.8
Bordeaux Mixture	10–10–50 dip	40.3	45.4	50.4	90.5
Monohydrated Copper Sulfate Lime Mixture	25% dust	22.8	28.3	75.8	85.3
Emulsified Phenol	1 to 100 for 10 minutes	19.8	25.0	100.0	100.0
Emulsified Cresol	1 to 100 for 10 minutes	24.7	23.5	100.0	100.0
Potassium Permanganate	1 to 100 for 10 minutes	29.8	39.0	100.0	100.0

The 6 and 10 percent hydroxymercurichlorophenol dust treatments maintained a reduced infection throughout the experiment and on October 10 showed only 42.3 and 41.8 percent infection respectively. The treatment with sulfur was the only other to show low infection by October 10. The infection on the sulfur-treated potatoes was 24.5 percent August 10, 33.7 percent September 3, and only 35.8 percent October 10. The 35 percent hydroxymercurichlorophenol treatment gave complete control, but as already shown caused severe retardation of germination. The reduction of infection following inoculations with spores was more pronounced for all chemical treatments than was obtained after treating diseased potatoes. Potassium permanganate 1 to 100 strength did not decrease infection when badly diseased potatoes were treated but held spore infection to 29.8 percent on June 1. A similar behavior was observed for other chemicals.

The results of treating sweet potatoes immediately after harvest on October 28 with disinfectants are given in table 7 for plants examined

February 20. Mercuric chloride, hydroxymercurichlorophenol and sulfur showed greater control than was reported in tables 1 and 2 for treatments made April 10 after storage. Mercuric chloride 1 to 1,000 for the 10- and 20-minute treatment allowed only 10 and 8 percent infected plants on newly harvested potatoes in comparison with 47.3 and 26 percent on potatoes treated April 10 after much shrinkage had occurred during the storage period. Hydroxymercurichlorophenol 1 to 10 strength reduced infection to 19 percent. The 6 and 10 percent dusts of this chemical reduced infection to 15 and 12 percent. Sulfur-treated potatoes showed 18 percent infection. Plants from potatoes receiving all other treatments showed 100 percent infection.

TABLE 7

THE RESULTS OF TREATING SCURFED SWEET POTATOES IMMEDIATELY AFTER HARVEST WITH DISINFECTANTS FOR THE CONTROL OF THE SCURF DISEASE

Chemical Treatment	Strength and Amount applied Oct. 28	Plants Scurfed Feb. 20 Percent
Check (Not Diseased)		0
Check (Diseased)		100.0
Mercuric Chloride	1 to 1000 for 10 minutes	10.0
Mercuric Chloride	1 to 1000 for 20 minutes	8.0
Sulfur	100%	18.0
Hydroxymercurichlorophenol	1 to 10 dip	19.0
Hydroxymercurichlorophenol	6% dust	15.0
Hydroxymercurichlorophenol	10% dust	12.0
Bordeaux Mixture	20–20–50 dip	100.0
Bordeaux Mixture	50–50–50 dip	100.0
Monohydrated Copper Sulfate-Lime	25% dust	100.0
Monohydrated Copper Sulfate-Lime	50% dust	100.0
Copper Carbonate	50% dust	100.0
Lime (Hydrated)	Dust	100.0
Formaldehyde	1 to 100 for 15 minutes	100.0
Phenoco	1 to 100 for 15 minutes	100.0
Lysol	1 to 100 for 15 minutes	100.0

DESTRUCTION OF DISEASED PERIDERM-TISSUE

The slightly greater control obtained in treating scurfed potatoes immediately after harvest in comparison to those treated after storage can be attributed to the fact that periderm cells cease to be sloughed off when the potato is cured, while the periderm tissue increases in depth, and at the same time the sclerotial formation apparently continues to develop. The sclerotial-like mycelium which is most prominent in badly scurfed tissue is probably resistant to chemical treatment. It was also found that the infected periderm could be removed in other ways.

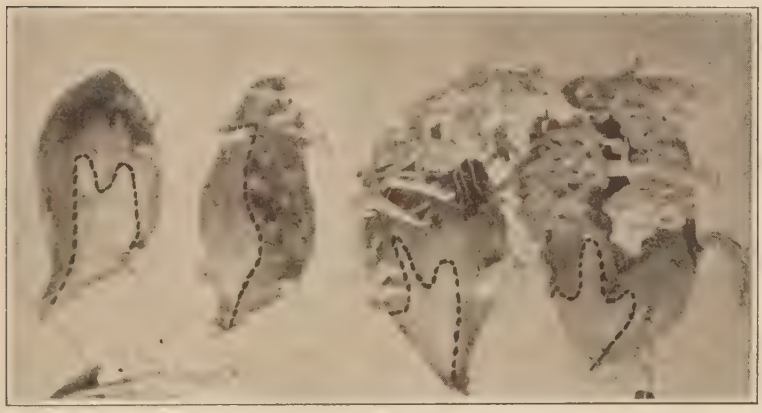

Fig. 13—Potatoes inoculated with a pure culture of the organism at the time of bedding showing spreading activities during the progress of plant development.

Diseased tissue was removed by cutting to the cortex but not to the cambium with a sterile knife. The potatoes were washed for an hour in running water to remove any contamination that would occur during the removal of the infected tissue. The potatoes were then dried rapidly to prevent *Rhizopus* infection and to obtain a calloused surface and bedded immediately in slightly moistened sand. The results are given in table 8. By June 1 the diseased potatoes used for a check gave 100 percent plant infection. No infection occurred on potatoes with the disease removed. Slightly fewer plants were produced on the peeled potatoes than on check lots, because some of the peeled potatoes decayed with soft rots. This would appear to be a means of eliminating the infection, but it would be difficult to apply practically because of the large amount of attention that would be required to remove the infection. The fungus was killed with concentrated sulfuric acid when badly diseased potatoes were immersed until the infected periderm was destroyed. Some difficulty, however, was experienced in determining the duration of the treatment necessary to destroy the fungus without greatly suppressing germination.

TABLE 8

THE RESULTS OF CUTTING OUT DISEASED TISSUES ON THE CONTROL OF THE SCURF DISEASE

Treatment	Plants June 1	Plants Scurfed Percent June 1	Plants Scurfed Percent Aug. 1
Check (Not Diseased)	382	0	0
Check (Diseased)	325	100.0	100.0
Disease Removed	285	0	0

INFLUENCE OF THE HYDROGEN-ION REACTION ON THE CONTROL OF MONILOCHAETES INFUSCANS

The cell sap of four sweet potato varieties is nearly neutral. When small potatoes were grown in a soil of pH 6.0 the hydrogen-ion was pH 6.707 for Red Jersey, pH 6.604 for Vineless Yellow Jersey, pH 6.736 for Norton Yam, and pH 6.756 for Porto Rico. These reactions are obviously favorable for *Monilochaetes infuscans* which has an optimum growth range between pH 5.5 and pH 7.0 (11). In further investigations on this subject, two media were employed: namely, Cook's number 2, a synthetic medium, slightly modified and consisting of 10 grams dextrose, 3 grams peptone, 1 gram dipotassium phosphate, 1 gram magnesium sulfate, and 1,000 cc. water, and a sweet potato medium already described in connection with the pure culture studies with disinfectants. Both media are very satisfactory for growing *Monilochaetes infuscans*. The latter was most satisfactory for preparing the hydrogen-ion and hydroxyl-ion ranges, because the adjusted reactions remained more constant than in the synthetic medium.

The media were prepared in amounts of a liter for each reaction and were adjusted with commercially pure hydrochloric acid and potassium hydroxide. It was allocated in 25, 50, and 100 cc. amounts in small Ehrlenmeyer flasks, steamed in some instances and well autoclaved in others, incubated for three days at 25 degrees Centigrade, and inoculated with both mycelium and spores grown in test tubes in large amounts for this work. The entire procedure was repeated twice with each medium using 10 flasks for each reaction. A summary of all trials is given in table 9.

The reactions were determined at intervals, especially after growth was first observed. All tests were continued for 30 days or longer. Growth did not take place in the reaction adjusted to pH 3.0. Slight development of the fine hyaline mycelium occurred at pH 3.5 (fig. 14). Neither spores nor dark hyphae developed in this culture. Growth was still weak in pH 4.0 and even in pH 4.5, but very few spores were produced in the former. The dark hyphae and spores were produced in the solution adjusted to pH 4.5. At pH 5.0 growth was good, and from pH 5.5 to pH 7.0 growth was so uniform that no effort was made to

TABLE 9

Influence of the Hydrogen-Ion Reaction on the Control of *Monilochaetes infuscans* When the Organism is Grown in Pure Cultures Adjusted to Definite Reactions

pH	Remarks
3.0	No growth.
3.5	Very weak growth. No spores formed.
4.0	Very weak growth and very few spores formed.
4.5	Weak and slow growth. Ability of fungus to produce spores and dark hyphæ begins.
5.0	Growth suppressed but good.
5.5	Excellent growth. Spores and dark hyphæ are produced in abundance.
6.0	Excellent growth. Spores and dark hyphæ are produced in abundance.
6.5	Excellent growth. Spores and dark hpyhæ are produced in abundance.
7.0	Excellent growth. Spores and dark hyphæ are produced in abundance.
7.5	Growth slightly retarded.
8.0	Growth greatly retarded.

determine at what pH optimum growth occurred. In the higher reactions growth was good, but greatly retarded at pH 8.0. The tendency of the reaction was to change from either extreme toward the optimum growing reactions.

The behavior of the organism in the hydrogen-ion range from pH 3.5 to pH 5.0 raised the question as to whether or not it is capable of attacking the potato after growing for sometime in a high acid medium. When potatoes were placed in water adjusted to the same pH as the fungus and then inoculated with the fungus from the corresponding pure culture reaction, infection was very weak at pH 4.0. It was good but slow at pH 4.5 to pH 5.0, indicating that infection will occur at reactions slightly above the minimum growth range. Infection and the development of the disease occurred more slowly than when the vigorous culture was used. The results also show that reactions between pH 4.0 and pH 4.5 retard the fungus and also the disease on the plant and potato over that developed in less acid media.

SOIL TREATMENT FOR THE CONTROL OF SCURF

In certain areas, especially where sweet potatoes are grown continuously on the same soil or where the rotation is for one or two years, soil infection is of much importance. The first definite evidence that the fungus could be controlled by soil treatment was obtained from a series of comprehensive tests by the writer (9), (10), (11), (12), (13). It was

shown that from 300 to 600 pounds of sulfur applied broadcast per acre brought about an acid reaction which inhibited the growth of the fungus and greatly reduced infection of potatoes. The prevailing and natural soil reaction was found to vary from pH 5.6 to 6.2 in a large percentage of the lands used for growing sweet potatoes. When the reaction was adjusted and maintained at or below pH 4.5, a definite increase in clean potatoes was obtained. The soil reaction was reduced from pH 5.8 to pH 4.3 with an application of 300 pounds of sulfur and to pH 3.3 with 600 pounds of sulfur.

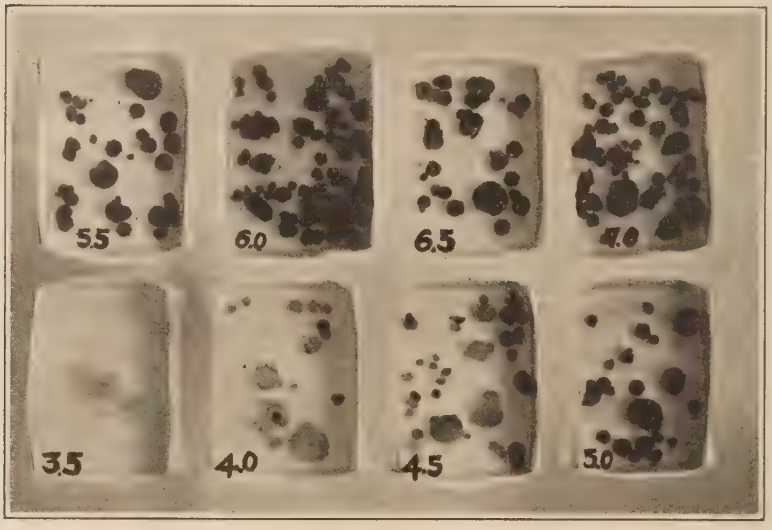

Fig. 14—Influence of hydrogen-ion reaction on the growth of *Monilochaetes infuscans.*

On some light sandy soils the reaction remained constant throughout the season. It was less stable on sandy loams and fertile sandy soils and gradually changed toward the original reaction. The large amounts of sulfur were injurious, especially on loamy soils. The injury was on plants recently transplanted. When the plants were well established very high acidity, pH 3.1, did not seem to disturb growth or yield. Sulfur was applied in the hill, row, and broadcast from two to four weeks before transplanting. The broadcast method gave the most uniform results. This method of application was applied practically on some soils and satisfactory results were obtained.

It was shown (3), (1), (9), that potatoes grown on soils treated with sulfur were smoother, and more highly colored than those grown on soils without sulfur and on limed soils and the lime also made acid soils more favorable for the growth of the fungus. Adams (1) recently obtained excellent control of scurf with inoculated sulfur, and gave results that compare favorably with those previously reported (9). He also reports increased yields and suggests that applications of sulfur are valu-

able as a sweet potato fertilizer. The application of sulfur to the soil was found to meet with some obstacles, which would prevent its use in all areas where scurf is severe.

It is probably acceptable, to biologists at least, that much of the oxidation of sulfur in the soil is brought about by microörganisms (24), (20), (21). The presence of these in any soil is variable from one season to another as changes in the soil become more or less favorable for their growth. The buffer reaction in some soils is so much greater than in others that it would be difficult to estimate the amount of sulfur necessary to maintain a controlling reaction for any soil type except by long time demonstrations. Changing the soil reaction was found to cause detrimental effects on other crops that follow sweet potatoes. The results therefore indicate that it would not be practical to apply sulfur to all soils infected with scurf, but that heavily infected soils, desirable for continuous growing of sweet potatoes, would in some instances justify applications of 300 pounds of sulfur per acre. It was also found that any finely ground sulfur could be applied and the cost of sulfur would permit its use in this way.

STUDIES OF ROOT AND STEM TREATMENTS FOR THE CONTROL OF SCURF

This investigation was undertaken in 1927 to determine whether any chemical applied to the roots and stems just before transplanting would arrest the fungus and prevent it from spreading from the stem to the roots and potatoes, even if it failed to kill the fungus. It had already been demonstrated that the sweet potato roots and stems would tolerate certain chemicals of fungicidal value (15). Harter (6) seems to be the only other investigator to conduct plant treatments for the control of scurf. After treating plants with Bordeaux mixture, formaldehyde, mercuric chloride, and lime sulfur he came to the conclusion, "that scurf can not be adequately controlled by either treating the potatoes alone or by immersing the plants in certain fungicides."

Observations since 1921 pointed strongly to the diseased plants as the principal source of infection. It is responsible for most of the infection in New Jersey, North Carolina, and South Carolina and probably other states. The organism spreads readily from the diseased potato to the plant so that a slight infection of the potato may result in 100 percent infection of the plants. Heavy seed potato infection always gives 100 percent infection of plants. In practice badly diseased potatoes are not used for seed purposes, but there is some disregard for slightly diseased potatoes, which are mostly bedded without treatment. The percentage of plant infection from the same seed stock is frequently variable because slightly diseased potatoes are sometimes bedded.

For this work badly diseased seed stock of the Yellow Jersey and Nancy Hall varieties were used and bedded in a fertile sandy loam because the heavy fertile soils are a better fungous medium and stimulate greater infection than sandy soils. These varieties were selected both because of their response to infection and their uniformity of yield of

potatoes near the stem. The Porto Rico variety was used on three farms only. The preparation of the land, fertilization and cultivation were the same as that universally followed in growing the sweet potato crop. Tests were distributed on eight farms in different parts of the state. The locations were in centers and on farms where the disease was prevalent in other years. Some chemical compounds were applied as dusts; others as liquids. When liquids were used, the roots and stems were immersed and planted immediately while wet.

For the dust treatments, the chemical compound was placed in a 25-pound size coarse paper bag and plants in lots of 50 and 100 were set into the bags with roots and stems downward. The roots and stem became well-coated with the compound without treating the tops by shaking the bags. In using a substance like sulfur with the roots turgid but not wet immediately before treating, 100 plants held .0005 pounds of sulfur. On this basis 10,000 plants, the approximate number set per acre, would require 5 pounds. When dipped into water immediately before treating one plant held .004 pounds and 10,000 held 40 pounds. The maximum amount of dust mixtures that the roots and stems would hold had to be used to obtain uniform treatment. When smaller amounts were used some parts of the plant would not be treated and other parts would become better coated with the sulfur. During these studies, the roots were maintained turgid after removing plants from the plant bed and until transplanted.

Best results in obtaining stands with plants treated and not treated, were obtained when plants were watered immediately after transplanting or when set with sufficient soil moisture available to give immediate growth response. The period of growth was from May 15 and June 1 to October 20 and November 20, the same time and the average growing period for the commercial crop. The same tests were conducted on five or more farms, and each was repeated, so that from 300 to 500 plants were used for each treatment. At harvest, each individual plant consisting of stem, roots, and potatoes was removed with a spading fork. The potatoes were removed from the stem and sorted into lots according to grades and amounts of infection. Data were obtained for (1) plant infection, (2) total potatoes, (3) potatoes infected, (4) potatoes badly infected, (5) number of salable potatoes, (6) salable potatoes badly infected, (7) weight of salable potatoes, and (8) weight of culls. A scale graduated to 10-gram units weighing up to 1,000 grams placed on a small stool, which was readily moved from one plant to another was used to weigh the potatoes. By this method it is obvious that some soil was weighed along with the potatoes, but weights were obtained before any shrinkage occurred, and when the sand was sufficiently dry so that only slight amounts remained on the potatoes when harvested.

Preliminary tests in pots in the greenhouse suggested for this work a number of chemicals which were tested during 1928. The results of this test are given in table 10. The control check gave both clean plants and potatoes November 1, indicating that the soil used was not infected. The infection was 100 percent for plants not treated. The scurfed potatoes on these same plants amounted to 42 percent. The 25 percent

monohydrated copper sulfate and 75 percent hydrated lime mixture, 20-20-50 and 40-40-50 Bordeaux mixtures, potassium permanganate, and lime permitted 100 percent plant infection, and further increased the percentage of scurfed potatoes by 2.0, 7.0, 18.4, 14.0, and 36.0 percent respectively. A 10 percent hydroxymercurichlorophenol compound in a

Fig. 15.—Rough, lignified surface of badly scurfed potatoes.

strength of 1 to 20 solution used as a dip permitted 40.0 percent plant infection and 24.8 percent diseased potatoes. Plants treated with finely ground sulfur showed only 4.3 percent plant and 1.7 percent potato infection. A colloidal sulfur (Kolodust) showed 13.5 percent plant infection and 5.5 percent potato infection.

Since diseased plants were used to make the treatments, it is necessary to explain here how plant infection was determined at harvest. When the fungus was active the stem part was almost completely blackened, and was rough and scaley in appearance. The smaller roots and other parts formed nearest to the stem were equally as badly diseased (fig. 15). Where sulfur was used the external tissue was healthy and similar in appearance to that of the healthy plants set for the control check because the diseased tissue was sloughed off and new disease-free periderm tissue was formed. The acidity produced by the sulfur, which had not completely oxidized when the plants were harvested, had either killed the fungus or prevented it from developing further. On some plants black, bark-like parts of the diseased tissue were not completely shed.

This is rather a remarkable phenomenon since stems of plants of the Nancy Hall variety are one-eighth to one-fourth inch in diameter when transplanted, but increase in diameter from one-fourth to three-fourths inch during the growing season besides sloughing off the outer parts of a continuously forming periderm. The fungus grew well in a sweet potato liquid medium containing 20 percent sulfur, but it did not fruit (fig. 7). The colonies were gelatinous or sponge-like. These pure culture studies indicate that sulfur as a chemical gives very slight fungicidal control of the organism.

The results of treating scurfed Nancy Hall plants and transplanting on Granville sandy loam are given in table 11. Every step in this test was conducted under ideal conditions. The land was not cropped the previous year and was in excellent physical condition. The soil was slightly moist when plants were treated and transplanted May 29, and a heavy rain during the afternoon after the plants were set assured a perfect stand which was maintained throughout the season. Observations on the development of vines indicated that none of the treatments were toxic or sufficiently injurious to the plant to develop external symptoms. The rainfall was above normal for the season, making a very satisfactory condition for the fungus to develop and spread.

TABLE 10

THE EFFECTS OF TREATING SCURFED YELLOW JERSEY SWEET POTATO PLANT STEMS AND ROOTS WITH DISINFECTANTS IMMEDIATELY BEFORE TRANSPLANTING ON THE CONTROL OF THE SCURF DISEASE

Chemical Treatment	Strength and Amount Used June 1	Plants Scurfed Nov. 1 Percent	Potatoes Diseased Nov. 1 %
Check (Not Diseased)		0	0
Check (Diseased)		100.0	42.0
Sulfur	100%	4.3	1.7
Sulfur (Colloidal) (a)	90%	13.5	5.5
Hydroxymercurichlorophenol 10%	1 to 20 dip	40.0	24.8
Monohydrated Copper Sulfate and Lime	25% dust	100.0	44.0
Bordeaux Mixture	20-20-50	100.0	49.0
Bordeaux Mixture	40-40-50	100.0	60.4
Potassium Permanganate	1 to 100	100.0	56.0
Lime (Hydrated)	1 to 10	100.00	78.0

(a)—Kolodust product of Niagara Sprayer Company.

TABLE 11

The Results of Treating Scurfed Nancy Hall Sweet Potato Plants With Chemical Compounds and Transplanting on Granville Sandy Loam Soil For the Control of the Scurf Disease

Treatment and Chemical	Strength and Amount	Plants Scurfed Percent	Potatoes Diseased Percent	Potatoes badly diseased Percent	Yield per acre bu. No. 1 & 2 Grade	Total Yield per acre bu.
Check (Not Diseased)		0	0	0	343.8	386.4
Check (Diseased)		100.0	86.1	52.4	324.8	341.5
Sulfur	100% dust	0	0	0	319.3	337.3
Sulfur (Colloidal)	90%	8.0	6.1	2.9	317.9	341.2
Sulfur 100% Monohydrated Copper Sulfate and Lime dust 25%	50% each	28.0	18.3	8.6	316.7	334.3
Hydroxymercurichlorophenol	1 to 5 dip	8.0	4.1	2.3	309.2	342.5
Hydroxymercurichlorophenol	1 to 10 dip	30.0	16.9	11.0	315.3	331.8
Calcium Sulfide	1 to 5 dip	92.0	76.1	40.5	298.6	340.9
Lime (Hydrated)	Dust	100.0	79.9	50.7	317.3	327.7
Lime Sulfur	1 to 5 dip	82.0	44.9	22.6	281.0	325.6
Monohydrated Copper Sulfate Lime 25-75	Dust	90.0	73.8	42.9	301.5	347.7

The diseased check plants showed 100 percent infected plants, 86.1 percent diseased potatoes, and 52.4 percent badly diseased potatoes. The control check of this experiment was obtained by cutting plants with aerial roots three to six inches above the ground, in order to avoid contamination as a source of infection. When harvested the plants and potatoes were both free from scurf. Finely ground sulfur used as a dust completely controlled the disease. Slight infection occurred where colloidal sulfur was used, but infection was only 8.0 percent for plants, 6.1 percent for potatoes, and 2.9 percent for badly diseased potatoes. A mechanical dust prepared by mixing by weight equal parts of sulfur and the mixture containing 25 percent monohydrated copper sulfate and 75 percent hydrated lime reduced infection 72 percent for plants, 67.8 percent for potatoes and 43.8 percent for badly infected potatoes. The plants treated with 10 percent hydroxymercurichlorophenol in 1 to 5 water dilution showed only 8 percent infected plants, 4.1 percent scurfed potatoes, and 2.3 percent badly scurfed potatoes. The same chemical 1 to 10 strength was not as effective as the 1 to 5 strength, the control given was 22.0, 10.8, and 8.7 percent less. However, this 69.2 percent reduction of diseased potatoes and 41.4 percent reduction of badly diseased potatoes is a result that may be considered satisfactory for practical application.

Other tests conducted with similar strengths of a mixture containing 6 percent hydroxymercurichlorophenol and 2 percent hydroxymercurinitrophenol gave results equally as good as the hydroxymercurichlorophenol used alone. A 10 percent hydroxymercuricresol in similar strengths also gave equally as good control and may be used. Lime sulfur, calcium sulfide, and copper lime dust gave only slight reduction. Lime treatments showed infection of the same intensity as that produced on the diseased check plants. The yields obtained in this experiment are so nearly equal for all treatments that only a brief discussion will give full explanation. The healthy check of plants abscissed three to six inches above the soil gave a yield of 44.9 bushels over the diseased check plants. The difference noted here is not one brought about due to scurf infection, but to some unknown phenomena. It would seem from the yields obtained that none of the chemicals increased production over the controls. Sulfur showed a loss of 5.5 bushels of salable potatoes per acre.

Fig. 16—The results of applying sulfur to the diseased stem: (a) Badly diseased 5 percent, (b) Slightly diseased 10 percent, and (c) Healthy 85 percent.

It is interesting at this point to consider the results of some data taken in this experiment on the yield of individual plants. Irregular production even on plants in such close proximity as 18 inches is often obtained. Extremes may be offered in which plant number 14 produced 1,150 grams of salable potatoes and plant number 15 only 18 inches away produced 130 grams, although it was healthy in every way (table 12).

A very large percentage of the plants produced from 500 to 1,000 grams of salable potatoes. This condition while not so striking occurs in any test and it seems doubtful that competition is the primary cause, nor does the position in the soil in relation to fertilizer and moisture account for the differences.

The size of the plants and root system seems to be a possible factor, since the cut plants were more uniform in size and gave more uniform yields in all experimental tests than did plants with primary roots. In spite of the differences in yield of individual plants the averages from 300 to 500 hills seems to eliminate much of an experimental error that would be certain to occur if fewer hills were used. But other than to show whether the chemical actually reduces or increases production would be beyond the scope of this treatise, because the finding of a chemical that will control scurf without either increasing or decreasing the yield fulfills the aims of this problem.

Fig. 17.—The results of planting a diseased plant: (a) Badly diseased potatoes 43 percent, (b) Slightly diseased potatoes 44 percent, and (c) Healthy potatoes 13 percent.

A sample of data from complete notes as taken at harvest for check plants not diseased, check plants diseased, diseased plants treated with sulfur and diseased plants treated with hydroxymercurichlorophenol are also given in table 12. Under (a) plant infection is noted by "1," no infection by "0." There is no infection showing on plants treated with sulfur and healthy check plants. For example, three plants are infected among those given for hydroxymercurichlorophenol treatment. Others

are (b) total potatoes of all sizes on the plant, (c) potatoes infected, (d) potatoes badly infected, (e) salable potatoes, (f) salable potatoes weight in grams, and (g) culls weight in grams. It is interesting to observe the behavior of infection on individual hills as seen in these results.

Plant number 1 of the check diseased plant has 6 potatoes; 5 are diseased; none badly diseased. Compare with plant number 5 with 3 potatoes, all 3 diseased and badly diseased. Plant 6 shows all potatoes scurfed, but none badly scurfed. Plant 14, with 6 potatoes, shows one diseased and none badly diseased. On light sandy soils, where the reaction was less favorable for the growth of the fungus, the infection was mostly confined to the potatoes below the stem. On loamy soils a favorable soil reaction caused a much larger percentage of badly infected potatoes than occurred on light sandy soils. The scurfed potatoes are those showing any amount of infection from a single spot to the entire potato. The badly diseased potatoes are those showing one-fourth to complete discoloration of the external parts, the condition that results in much shrinkage and low sale value.

A discussion on the relation of the time of harvest to the severeness of the scurf disease of sweet potatoes (12) showed that potatoes harvested in August and the early part of September were much less scurfed than those harvested later in October and November. Studies at that time and since indicate that the differences were not due to greater susceptibility of more so-called mature roots or potatoes, but to a factor of greater abundance of the inoculum. An early harvest such as would be required to obtain a large percentage of clean potatoes could possibly be practiced

TABLE 12

THE DATA OBTAINED FROM INDIVIDUAL HILLS SHOWING (a) 0. PLANT NOT INFECTED, 1. PLANT INFECTED; (b) TOTAL POTATOES; (c) POTATOES INFECTED; (d) POTATOES BADLY INFECTED; (e) SALABLE POTATOES; (f) SALABLE POTATOES WEIGHT IN GRAMS; (g) CULLS WEIGHT IN GRAMS.

Check Not Diseased

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(a)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(b)	11	11	6	5	11	4	5	10	11	11	6	5	6	9	5	3	9	5	5	4
(c)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(e)	1	4	4	3	5	3	4	7	7	5	5	5	6	5	1	3	8	5	4	3
(f)	150	340	755	520	520	580	485	550	350	980	720	910	930	1150	130	800	1210	1040	1100	1250
(g)	480	290	170	110	165	45	110	0	192	360	130	670	0	160	120	0	150	110	25	40

TABLE 12—*Continued*

Check Diseased

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(a)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
(b)	6	8	3	6	3	4	5	3	6	7	5	4	5	6	5	5	6	5	6	5
(c)	5	8	1	6	3	4	5	3	6	7	5	4	5	1	3	5	1	5	6	2
(d)	0	1	0	0	3	0	5	0	2	6	2	2	5	0	1	1	1	2	2	1
(e)	2	2	3	2	3	2	4	2	2	3	2	4	4	4	4	4	3	5	5	3
(f)	240	400	605	440	760	680	860	760	690	520	580	1000	960	1230	1000	810	520	1140	700	360
(g)	200	230	0	90	0	110	90	90	90	320	200	150	90	200	0	50	320	120	260	130

Sulfur:

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(a)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(b)	6	5	8	4	8	5	8	6	6	5	6	8	7	4	3	8	4	9	5	6
(c)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(e)	3	2	6	2	4	5	5	3	3	3	5	5	4	4	2	8	3	6	4	5
(f)	420	270	670	180	580	700	870	860	580	540	1150	1140	1100	820	370	1440	500	1090	580	720
(g)	140	160	240	140	180	80	130	220	160	0	0	110	170	0	0	200	120	60	30	30

Ten Percent Hydroxymercurichlorophenol 1 to 5:

Plant	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(a)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1
(b)	6	5	4	4	4	5	9	5	4	6	8	9	2	7	5	6	5	4	6	5
(c)	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	3
(d)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	2
(e)	4	2	2	4	4	4	7	4	2	3	5	8	2	6	2	2	3	4	5	3
(f)	410	570	440	1200	880	730	955	910	250	935	905	1430	405	1130	480	680	790	970	1070	980
(g)	170	60	10	0	0	55	160	90	90	130	85	290	0	40	111	250	220	0	75	120

to advantage where part of the crop is harvested so-called prematurely for early sales, but an early harvest of September would conflict with the many other advantages attained in a harvest from October to November.

A series of field experiments were conducted with mechanical mixtures of sulfur and hydrated lime to determine to what extent, if any, sulfur is active as a fungicide, since the lime would maintain an alkaline soil reaction or prevent the formation of such an acid reaction as would be necessary to inhibit growth. For this test sulfur was mixed with lime to make 75, 50, and 25 percent dry mixture by weight. The results are given in table 13.

The check of plants not scurfed when transplanted showed no infection at harvest. The diseased plants when harvested showed an infection of 100 percent for plants, 81.3 percent for potatoes, 48.6 percent for potatoes badly diseased, and 52.9 percent for salable potatoes badly diseased. No infection occurred where sulfur was applied alone on the plants. The mixture containing 75 percent sulfur and 25 percent hydrated lime mixed 24 hours before using allowed 38 percent plant infection, 20.8 percent potato infection, 10.5 percent potatoes badly diseased and 10 percent salable potatoes badly diseased. A reduction over the check of 62, 60.5, 38.1, and 42.9 percent respectively.

There would seem to be an inhibiting factor of sulfur toxicity indicated in these results, but the reaction on the plant stem at harvest was sufficiently acid to reduce the fungous growth and give the major control. Where 50 percent each of sulfur and lime was used infection was equal to that on the check. The 25 percent sulfur and 75 percent lime and lime used alone showed increases in infection. Infection on the latter

TABLE 13

THE RESULTS OF TREATING SCURFED ROOTS AND STEMS WITH DIFFERENT AMOUNTS OF SULFUR IMPREGNATED WITH HYDRATED LIME ON THE CONTROL OF THE SCURF DISEASE

Treatment	Strength	Plants Scurfed Percent	Potatoes Diseased Percent	Potatoes Badly Diseased Percent	Potatoes Salable Badly Diseased	Yield Per Acre Bushel
Check (Not Diseased)		0	0	0	0	350.0
Check (Diseased)		100.0	81.3	48.6	52.9	345.0
Sulfur	100%	0	0	0	0	352.5
Sulfur and Lime	75% and 25%	38.0	20.8	10.5	10.0	345.8
Sulfur and Lime	50% and 50%	100.0	81.9	36.2	44.5	364.3
Sulfur and Lime	25% and 75%	100.0	88.5	49.3	56.7	336.3
Lime	100%	100.0	94.3	50.9	54.4	344.7

was 100 percent for plants, 94.3 percent for potatoes, 50.9 percent for potatoes badly diseased and 54.4 percent for salable potatoes badly diseased, an increase over the check of 0, 13.0, 2.3, 1.5. The yields were nearly equal for all treatments and checks.

In another test in which sulfur was mixed with a neutral mineral clay to make strengths of 10, 20, 40, 60, and 80 percent the results as given in table 14 show that amounts of sulfur as small as 10 percent greatly reduced infection, which was 14.1 percent for all potatoes and 7.6 percent for badly scurfed potatoes in comparison with 86.9 and 34.1

TABLE 14

The Results of Treating Scurfed Roots and Stems With Various Amounts of Sulfur Mixed With Mineral Clay on the Control of the Scurf Disease

Chemical Treatment	Amount	Potatoes Diseased Percent	Potatoes badly diseased %	Yield Per Acre Bushel
Check (Not Diseased)		0.0	0	157.7
Check (Diseased)		86.9	34.1	131.5
Sulfur	100%	2.7	0	138.1
Sulfur	80%	2.8	0	120.1
Sulfur	60%	4.0	0	124.8
Sulfur	40%	5.3	0	121.2
Sulfur	20%	13.9	7.5	133.4
Sulfur	10%	14.1	7.6	132.6

percent respectively for the check. The infection of potatoes on plants treated with 100, 80, 60, and 40 percent sulfur was 2.7, 2.8, 4.0, and 5.3 respectively with no badly infected potatoes. The yields were not affected by the treatments. The check of healthy plants obtained by cutting stems above the soil produced 157.7 bushels per acre or 26.2 bushels more than the diseased plants.

TABLE 15

The Results of Treating Turgid Scurfed Roots and Stems With Sulfur When External Plant Parts Are Wet and Dry

Treatment	Condition of roots and stem	Potatoes Diseased on Granville sandy loam Percent	Potatoes Diseased on Norfolk sandy loam Percent	Potatoes Diseased on Durham sand Percent	Potatoes Diseased on Cecil sandy loam Percent	Potatoes Diseased on Congaree silt loam %
Sulfur 100%	Wet	0	0	0	1.2	5.6
Sulfur 100%	Not Wet	5.2	0	1.9	4.5	21.9
Check (Diseased)		81.3	13.0	82.2	83.5	84.3

Where the soil reactions are pH 5.0 to 5.5 to begin with the small amounts of sulfur gave practical control. On loamy soils the larger amounts were necessary to obtain satisfactory control. The larger amounts of sulfur did not kill Yellow Jersey, Nancy Hall, and Porto Rico plants, the only varieties used, in any of the eight tests on different farms. On the loamy soils slight injury and sometimes almost complete destruction of the lower extremities of the stem was observed during harvest. This type of injury was only seen on plants where the roots were dipped in water before applying the sulfur. It was probably caused by the absorption of the acid developed on the stem.

A comparison of the effectiveness of the sulfur applied immediately after wetting the roots and stems and surface dried roots and stems on Granville sandy loam, Norfolk sandy loam, Durham sandy loam, Cecil sandy loam, and Congaree silt loam is given in table 15. The diseased check plants of these different soils was 81.3, 13.0, 82.2, 83.5, and 84.3 percent respectively. It was approximately the same for all soils except the Norfolk sand, which had 68.3 percent less diseased potatoes than occurred on the Granville sandy loam. Sulfur applied to turgid roots controlled the disease on the Norfolk sand. Infection of potatoes was 5.2 percent on Granville sandy loam, 1.9 percent on Durham sandy loam, 4.5 percent on Cecil sandy loam, and 21.9 percent on Congaree silt loam, or reductions over the check of 76.1, 80.3, 79.0, and 52.4 percent for the different soil types. The application of sulfur to wet roots gave the most efficient control, since diseased potatoes occurred on two soil types only, and amounted to 1.2 percent diseased potatoes on the Cecil sandy loam, and 5.6 percent on the Congaree silt loam.

These results favor the use of sulfur on wet roots and stems, but an application on the roots not wet gives satisfactory control and is suggested for general use until further information is obtained on its behavior on a wide range of soils. In treating the roots with a dry surface the maximum infection of potatoes on sandy soils well adapted to sweet potatoes was 15 percent scurfed and 5 percent badly scurfed (fig. 16). An average of the checks on the same soils show 87 percent scurfed and 43 percent badly scurfed, a difference in clean potatoes of 72 percent (fig. 17).

The reaction on stems receiving the various treatments was determined at harvest for the field tests and at various periods in pot studies. The oxidation of sulfur was gradual, but more rapid on loamy soils. In 10 days the reaction on the stem of plants treated with sulfur and transplanted in a sandy loam had advanced to pH 5.0 from pH 6.0 and in 30 days to pH 4.2. The reaction on sulfured plants finally reached an acidity as great as pH 3.0 to pH 4.0, which was maintained until harvest when sulfur was still abundant in different amounts on all plants, but more so on soils of the Norfolk type.

In view of the results obtained in the study of the influence of the hydrogen-ion reaction on the growth of *Monilochaetes infuscans* in pure culture it is obvious that a reaction between pH 3.0 and 4.0 obtained on the stems of the plants is the controlling factor. Some of the acid was

diffused into the soil, since soil in the vicinity of the plant where sulfur was used became more acid and where lime was used more alkaline. The greatest acidity obtained was on the stem. Where sulfur and lime were mixed the reaction was acid where the largest amount of sulfur and smallest amount of lime were used, but neutral to very slightly alkaline where lime was used in amounts of 50 percent or more. It would seem from the results of this work that the soils used in these tests carried a satisfactory oxidizing group of microörganisms and special inoculation of the sulfur is not necessary to secure the oxidation and acidity necessary for controlling scurf.

METHODS OF OBTAINING HEALTHY SEED STOCK

The selection of disease-free seed stock probably dates back to the time when vine cuttings were used to supplement plants for transplanting definite areas of land. This is a profitable procedure throughout the South and is practiced widely, in many instances perhaps with no thought of disease control. The clean potatoes, especially potatoes without scurf and black rot diseases produced on vine cuttings were probably so clean in comparison to the potatoes obtained from slips that the idea suggested itself as a practical procedure and became a common practice. The selection of seed stock and plants was carried out in several ways.

These questions are often raised as to the value of each in the control of scurf: Is it possible to select good seed from the bin? Would cutting away the ends of plants joined to the potato eliminate infection when plants are grown on diseased potatoes? What is the best procedure or procedures to follow in obtaining good seed? Experiments were conducted with potatoes obtained from vine cuttings, diseased potatoes, and apparently healthy potatoes from the bin. Diseased potatoes were bedded in sandy loam, and in sand.

When the plants from these various lots were of sufficient size to transplant, the planting as shown in table 16 was carried out. (1) Plants from potatoes grown from vines cut from other plants in the field and transplanted according to the general procedure for growing vine cuttings. (2) Plants from the badly diseased potatoes. (3) Plants from apparently healthy potatoes selected from among diseased potatoes in bins. (4) Plants grown on diseased potatoes in sandy loam and roots and stems cut two inches above the end attached to the potato. (5) Plants grown on diseased potatoes in sand and cut two inches above the potato. (6) Plants from diseased potatoes in which the plants had been forced to produce rank tall growth in the plant bed with aerial roots on nodes three to six inches above the soil. In obtaining the latter, abscission was made in not less than three inches of the ground.

The results show no infection of plants and potatoes for the test with potatoes from vine cuttings (fig. 17). The diseased plants produced 94.3 percent scurfed potatoes and 50.9 percent badly scurfed potatoes. The bin selection gave 60 percent diseased plants, 65.2 percent diseased potatoes and 38.2 percent badly scurfed potatoes. A decrease over the check of 40.0, 29.1, and 12.7 percent respectively. The roots and stems

of plants grown in sandy loam and cut two inches above the potato showed an infection equally as severe as that obtained with the diseased check. The roots were visibly infected and the disease symptoms determined on most of these plants before transplanting in the field. Plants grown in a sandy medium and cut two inches above the potato allowed an infection of 32.1 percent for plants, 22.3 percent for potatoes and 14.5 percent for potatoes badly infected, a reduction over the check of 67.9, 72.0, and 36.4 percent respectively for plants, potatoes, and potatoes badly diseased.

Fig. 18—Healthy potatoes and plants grown from healthy plants and potatoes.

The yield was uniform except for plants abscissed from three to six inches above the ground, in which the production was 421.6 bushels per acre, an increase over the check of 35.2 bushels per acre, similar in trend to that already discussed. This test indicates two possible means of obtaining good seed; namely, (1) Establishing early plantings, for vine settings; (2) Forcing plants in the plant bed to obtain rank growth and aerial roots. The latter suggests a more practical method than making vine cuttings, since greater uniformity of size and more uniform stands in the field are made possible by developing before transplanting the roots, which are more slowly developed on vine cuttings during drought periods. The latter method requires the application of manures,

especially nitrogen and an abundance of water, in which partial shading helps to conserve the moisture. The bin selection fails because of indeterminate infection.

The cutting of the roots two inches above the infected potato has given greater control in some tests than the one reported here, but in such cases plants were pulled immediately after they showed the first leaf. The percentage of infection has been directly in proportion to the length of time that the plant is left attached to the potato, because it offers further time for the spreading fungus to reach to a greater height on the stem.

TABLE 16

The Value of Different Methods of Obtaining Healthy Seed Potato and Plant Stock For the Control of the Scurf Disease

Planting	Plants Scurfed Percent	Potatoes Diseased Percent	Potatoes Badly diseased %	Yield Per Acre Bushel
Check (Not Diseased) from vine cuttings	0	0	0	386.4
Check (Diseased)	100.0	94.3	50.9	380.6
Selected from bin and washed	60.0	65.2	38.2	383.9
Roots and stem cut two inches above the potato	95.4	91.2	45.8	384.1
Roots and stem cut two inches above the potato	32.1	22.3	14.5	379.5
Abscission three inches above the soil	0	0	0	421.6

DISCUSSION

The scurf disease of sweet potatoes was reported in 1890, and since that time has increased in importance. It causes from 7 to 15 percent loss. The diseased potatoes shrink badly and often become worthless for marketing. The present standard grading system which permits only a trace of scurf greatly increases the importance of the disease because the diseased potatoes can not be sold as easily as formerly. The shipper and consumer are responsible for the elimination of scurf from good grades. However, the scurfed potatoes, except when shrinkage is severe, are not discriminated against on home markets. They are also fed to hogs and therefore are not a total loss. The losses affect the commercial grower most, because potatoes free from scurf are reselected after storage, and the discarded scurfed potatoes sometimes rot badly, when various soft and dry rot producing fungi invade the newly bruised areas, unless they can be disposed of shortly after being rehandled.

The causal fungus spreads from the potato to the plant in the plant bed and from the plant to the potatoes in the field. The diseased potato is the principal source of infection and even when slightly diseased produces 100 percent infection of plants. The organism spreads up the stem

and along the roots by means of mycelium, which grows best in soils containing an abundance of organic matter. Spores spread in water from the stem downward through crevices produced in the soil by the enlarging potato. Both plants and potatoes are widely distributed from one state and locality to another. The .present wide dissemination is mostly due to the use of diseased plants.

Certified seed has not helped much in preventing dissemination of this disease, because even a trace of infection, which is allowed by most regulations may and often does result in complete infection when diseased and healthy plants are dipped together in the same water to correct temporary wilting. Slight infection is also sufficient to inoculate the soil, which becomes a minor source of infection. To prevent further dissemination all traces of the disease from seed stock is necessary. Complete elimination of the disease in certified seed is successfully practiced in this state. Although the disease is widely disseminated a large amount of potatoes free from scurf are grown, showing that a tolerance of scurf is not necessary to fill the demands for certified seed.

There is no epidermis on the sweet potato except on very young roots. There is a well defined periderm in which the outer cell walls are broken. *Monilochaetes infuscans* enters the periderm so readily that there is no question but that the open cells enable the very small mycelium to enter. An intracellular sclerotial formation of the mycelium develops in the upper cells, from which the sporophores arise. These sclerotia continue to form in other cells of the periderm as the outer cells are sloughed off. The mycelium on the surface is dark-colored and septate. The small hyaline mycelium penetrates the periderm and produces haustoria-like bodies in the tissues some distance below the surface. Spores are produced in great abundance in both soil and pure culture.

Seed treatment with mercuric chloride and formaldehyde has been recommended and used widely for treating seed sweet potatoes before bedding. Treating the diseased potato with mercuric chloride resulted in some but not a satisfactory control even when used in various strengths and for different lengths of treatment, as hot solutions, and presoaking the potatoes. Formaldehyde did not reduce scurf infection. A large number of chemicals, including hydroxymercurichlorophenol, were used for treating the diseased potato. A satisfactory control was not obtained. Mercuric chloride and hydroxymercurichlorophenol gave sufficient reductions of infection and either one or the other should be used since the treatment may be of some value in the control of other seed borne diseases. The 1 to 1,000 strength of mercuric chloride used for 15 minutes is preferable to stronger solutions and to shorter treatments with the same chemical. The strength can be maintained by adding two-fifths to one-half ounce to the original solution after treating each 10 bushels up to 50 bushels as suggested by Weimer.

The 10 percent hydroxymercurichlorophenol compound 1 to 10 solution used for dipping the potatoes is equally as effective as the mercuric chloride treatment. Dusting the potato with various strengths and mixtures of this and other organic mercury compounds greatly retarded germi-

nation and are not applicable to practical use, although excellent control was obtained when these were used as dust and paste treatments. When seed treatment is conducted for the control of scurf, it is essential to take every precaution against contamination.

The growth of *Monilochaetes infuscans* was inhibited in pure cultures containing amounts of chemicals much weaker than was applied to the potato. Furthermore, formaldehyde and other chemicals that gave no control of the fungus in the tissue of the potato controlled it in pure culture. This indicates that the sclerotial bodies are more resistant to the chemicals than both the mycelium and spore.

The diseased periderm was readily destroyed by peeling to the cortex and by dipping in concentrated sulfuric acid. Neither method is satisfactory for practical use. The removal of the periderm with a sharp knife is not detrimental to germination, except when the cambium is destroyed. The losses from soft rots when the peeled potato tissue is not calloused and the time necessary to carry out the peeling are factors that would prevent the use of this method. The sulfuric acid treatment was difficult to apply and injury to germination was sometimes severe.

In pure culture studies the fungus did not grow in a hydrogen-ion reaction of pH 3.0. Slight growth occurred at pH 3.5. Growth was greater but still weak at pH 4.0 to pH 4.5. Optimum growth lies somewhere between pH 5.5 and pH 7.0. Infection of potatoes occurred between pH 4.0 and pH 4.5 when sulfur was applied to the soil at the rate of 300 to 600 pounds to an acre. The soil reaction was reduced from pH 5.8 to pH 4.3 and pH 3.3 respectively. On light sandy soils excellent control of the disease was obtained and the high acidity did not injure the plants or affect the quantity of the yield. On loamy soils plant injury was severe. Greater control was obtained by broadcasting than by applying in the row and drill. When light sandy soil is badly infected and it is desirable to grow sweet potatoes on the same land for several consecutive years, an application of 300 pounds of sulfur to an acre should be economical and practical. This method is not applicable to all soils where the disease occurs and should not be used on soils where crops susceptible to acid injury are to follow sweet potatoes.

Studies on root and stem treatment with chemicals were conducted for the control of scurf. In preliminary tests it was shown that a large number of chemicals were either injurious to roots or not effective against the fungus. Sulfur was found to be a very weak fungicide for this fungus, but the sulfuric acid formed when it oxidized on the stem resulted in excellent control.

Pure sulfur applied to wet roots gave the greatest control. On loamy soils the amount adhering to the wet roots caused some injury to the stem, because of high acidity but in no case were plants killed by either the sulfur or high acidity which became as great as pH 3.0 on some stems while pH 4.0 arrested the growth of the fungus. The greatest hydrogen ion concentration formed well after the plant was established and probably explains why the injury was not more severe during the early growth of the plant. Pure sulfur applied to a dry but turgid

roots and stem was nearly as efficient in controlling the disease as when eight to ten times as much was applied to wet roots. It would seem from the results obtained in treating plants with sulfur that good control may be expected on any type of soil, but on very fertile and loamy soils sulfur may oxidize very rapidly, thereby creating an acidity that would injure the plants before the control of the fungus is completed. The 10 percent hydroxymercurichlorophenol, 6 to 8 percent hydroxymercurichlorophenol plus 2 percent hydroxymercurinitrophenol mixture, and 10 percent hydroxymercuricresol used in dilutions of 1 to 5 and 1 to 10 also gave excellent control of scurf, but were less effective than sulfur.

These results are applicable to certain suggestions that may be of value in making practical applications. Sulfur does not control stem rot, caused by *Fusarium batatatis*. Plants treated with sulfur and transplanted on soils infected with this organism may result in greater stem rot losses than plants not treated with sulfur. On lands badly infected with *Fusarium batatatis* it is therefore, questionable whether sulfur should be used. There is no distinct and well recognized line of demarcation between lands where ideal conditions exist for stem rot and those favoring scurf, because both diseases sometime appear together in the same soil. However, the light sandy soils are most favorable for stem rot, and are somewhat suppressive of the scurf disease because of unfavorable natural soil reactions. The more loamy soil types are most favorable for the development of *Monilochaetes infuscans* and the scurf disease and are apparently not well-suited for *Fusarium batatatis*, since stem rot is rarely severe on any other than the light sands.

Where stem rot is known to be severe 10 percent hydroxymercurichlorophenol in 90 percent inert material or 10 percent hydroxymercuricresol in the same amount of inert material added to water to make 1 to 10 strength is suggested for dipping the roots and stems immediately before planting. These substances are now on the market as "Semesans." Although these materials are not as effective as sulfur they have advantage over sulfur in being more effective against *Fusarium batatatis*.

The strength of 1 to 5 was more effective than the 1 to 10 strength, but 1 to 5 concentration sometimes caused severe injury and poor stands. The costs of the chemicals, the time for treating, and the apparatus necessary even for the large commercial acreages are insignificant and small. The entire cost where sulfur is used would be less than twenty-five cents an acre, and less than one dollar where hydroxymercurichlorophenol is used. The only apparatus needed regardless of the acreage is a tub for the liquid and several big paper bags for the dust.

The history of vine cuttings as a means of obtaining so-called disease-free seed is not known. The origin of the method probably dates back to the time when vine cuttings were used to supplement plants in transplanting larger acreage than the available plants would cover. It is a most commendable and not an expensive means of obtaining a good seed stock. Although this method of growing the seed stock is now practiced, and has been for many years, the amount of seed stock used from vine cuttings is far below what it should be. Perhaps the reasons why it is not universally accepted and practiced throughout the sweet potato area

may be attributed very largely to indifference and not a clear understanding of the disease on the part of many. Where healthy plants and seed stock are not available, a new method may be employed, even when the potatoes bedded are diseased. The healthy plants are obtained by forcing the plants to grow rank and dense under partially shaded conditions. This induces the formation of aerial roots. The plants are then obtained by cutting three or more inches above the soil and the diseased potato.

In carrying out demonstrations and suggesting recommendations it is advisable to point out the advantages of maintaining a turgid root system until the plants are transplanted regardless of whether or not plants are treated and to emphasize especially the advantages of transplanting during good moisture seasons or watering immediately after transplanting since the critical period in establishing a stand is immediately after transplanting. This is true whether or not plants are treated, and especially so for the latter.

SUMMARY

1. The sweet potato scurf disease, caused by *Monilochaetes infuscans*, is the most widely distributed disease of this crop, occurring in all and in many parts of states where the crop is grown.

2. The major effect on the potato is loss of market value due to the dark brown discoloration of the periderm tissues, and to desiccation and shrinkage. The brown discoloration or pigment is a product of the fungus, and is partly removed with ammonia water.

3. The causal organism produces an extremely small hyaline mycelium that readily penetrates the periderm tissue, short and large crowded club-like or sclerotial mycelium intracellular in the periderm and dark heavy mycelium on the surface. The sporophores are perpendicular to the surface of the infected tissue and prolific of hyaline spores in chains.

4. The fungus readily enters the periderm through the broken cell walls. It advances into other cells as the outer parts of the periderm are sloughed off during the growing season.

5. Dissemination is well carried out, since diseased potatoes and plants are widely exchanged in states and localities. The diseased potato and plant are major sources and the soil is a minor source of infection.

6. The fungus spreads in all directions to underground parts by the extension of the mycelium along the stem and roots, and the spores washed downward from the infected stem. The fungus spreads throughout the growing season and becomes most prominent late in the season due to a greater amount of spore inoculum.

7. The fungus grows well on extract media from manure, hays and many plant products, indicating to some extent its saprophytic life in the soil in the absence of the sweet potato, its only known host.

8. Pure culture studies in which disinfectants were added to make different strengths showed that a large number of chemicals inhibited the growth of the fungus and many of them in very weak dilutions.

9. Diseased seed potato treatment with strengths far greater than was found to inhibit growth in pure culture studies, resulted in only partial control for the mercury compounds, and no control for many compounds including formaldehyde. A 1 to 1,000 mercuric chloride treatment for 15 minutes and a 10 percent hydroxymercurichlorophenol solution of 1 to 10 gave the most satisfactory reduction of scurf. Hot chemicals and presoaking before treating only slightly increased the efficiency of the chemicals.

10. The disease was destroyed by removing the infected periderm with a sharp knife and by treating with concentrated sulfuric acid. Neither method is found applicable for practical use.

11. Growth of *Monilochaetes infuscans* is inhibited at pH 3.0 and is very weak between pH 3.5 and pH 4.0. This influence of the hydrogen-ion concentration on the growth of *Monilochaetes infuscans* was found to be a method of controlling the scurf disease.

12. Sulfur, which oxidizes and forms sulfuric acid in the soil, applied in amounts of 300 to 600 pounds per acre increased the soil acidity from pH 5.8 to pH 4.3 and pH 3.3, and inhibited the growth of *Monilochaetes infuscans* giving scurf free potatoes even when diseased plants were set. It generally left the soil more acid than is desirable for crops rotated with sweet potatoes. The soil treatment seems applicable to only the best sweet potato lands where good yields of high quality are obtained, and not for general application on every soil infected with the fungus.

13. Finely ground sulfur used as a dust application on turgid stems and roots with dry or only slightly moistened surfaces immediately preceding transplanting created such an acid reaction on the infected parts, before the fungus could spread to the potatoes, that it arrested and destroyed the causal organism. The infected tissues sloughed off during the growing period, resulting at harvest in both healthy stems and potatoes. Sulfur as a chemical is only a weak fungicide against *Monilochaetes infuscans.*

14. A 10 percent hydroxymercurichlorophenol with 90 percent inert material used as a dip in a dilution of 1 to 10 strength was less effective than sulfur, but gave results that were entirely practical. A 6 to 8 percent hydroxymercurichlorophenol and 2 percent hydroxymercurinitrophenol mixture and 10 percent hydroxymericresol compound were equally as effective as the hydroxymercurichlorophenol and may be used at the same strength.

15. The treatments were neither detrimental or beneficial to yield, and indicated that their usefulness is confined to the control of scurf.

16. The development of seed stock free from scurf by means of vine cuttings is used widely, but in a very limited way. It is found to be a

very practical and a certain means of controlling scurf if the soil used for growing the seed stock is not infected. Forcing plants in partially shaded plant beds until aerial roots are produced was found to be a certain and practical means of obtaining scurf-free plants, when such plants were abscissed three or more inches above the soil. Selection of apparently healthy potatoes from among diseased potatoes in the bin was not satisfactory.

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